INFORMATION GUIDE

ART + ENERGY

Flash Cards

LAND ART GENERATOR INITIATIVE

Dual language
English/Danish
INTRODUCTION

HELPFUL INFORMATION TO KNOW BEFORE USING THESE CARDS

Science, technology, engineering, design, and art all come together in the enclosed cards. The images on the front of each card represent ideas for large-scale works of public art that generate utility-scale clean electricity for cities. These artful power plants are designed to be safe to the natural environment, not create pollution, to generate energy for up to thousands of homes, and to make our public spaces more enjoyable. Some of them have the added benefit of edible gardens, habitats for animals, air filtration, data visualization, soil remediation, and areas for human recreation.

Any number of different technologies and materials can be incorporated into land art generators. And each employs a variety of methods for harvesting energy from natural resources such as the sun, the wind, biochemistry, and kinetic movement.

As you use these cards, think about what your design would look like for an energy generating artwork! What technologies would you use? How many homes could it power?

HOW TO DEFINE ELECTRICAL POWER

WHAT IS A WATT?
Unit of measure of electrical power equivalent to 1/746 horsepower

WHAT IS A WATT-HOUR?
A measure of electrical energy equivalent to one watt of power used or produced consistently over one hour of time

WHAT IS A KILOWATT (kW)?
Equal to 1,000 watts

WHAT IS A KILOWATT-HOUR (kWh)?
Equal to 1,000 watt-hours, or one kW output or consumption over one hour of time

WHAT IS A MEGAWATT-HOUR (MWh)?
A megawatt-hour is one million watts delivered continuously over one hour

WHY IS ELECTRICITY IMPORTANT?

Electricity is just one of many forms that energy can take (others include thermal, chemical, and mechanical), but it is one of the most versatile and useful, and it comprises around 40% of the total energy consumed by humans.

For the purposes of these exercises we will focus on electrical energy and on ways in which we can reduce our electricity consumption and limit the amount of greenhouse gas (GHG) emissions that result from the generation of electricity. The generation of electricity from fossil fuels contributes to global climate change by emitting greenhouse gases (like carbon dioxide, carbon monoxide, methane, and others), which trap solar heat in the Earth’s atmosphere.

The International Panel on Climate Change (IPCC) has concluded that we have passed the point where the quantity of GHG already in our atmosphere will cause a global mean temperature increase in the 21st century of 2°C, and that if we do not stop burning fossil fuels this number could rise to 4°C or even 6°C. The human consequences of this type of rapid shift to the delicate balance of our ecosystem are extreme and even if held at 2°C include mass population displacement, increase in disease, food and water shortages, and increase in severe weather events. It is therefore imperative that we work together to reduce our dependence on fossil fuels as the source of our energy as soon as possible.

Buildings account for 65% of electricity consumption (about half of that is residential use) so reducing the amount of electricity we consume at home will go a long way to reducing GHG emissions. And if we can replace the coal-fired and gas-fired power plants with clean and renewable electricity generation over the next decades, we may be able to cap the mean temperature increase to under 3°C and avert the worst impacts of global climate change.
The technology to make the shift from fossil fuels to renewable energy already exists. Scientists and engineers have been working over the past decades to make renewable energy more affordable and reliable, and we are now at a point where the total cost of generating electricity from non-polluting renewable sources is at parity with the cost of doing so with coal and oil. The challenge now is to convince a large number of people to get behind the change because it is going to take a massive collective effort and a shift in our everyday systems and economies.

As energy generation necessarily comes in closer proximity with the real estate that it powers, issues of aesthetics that drive acceptance are becoming more and more debated. Throughout history, the urban environment has undergone continuous design reinterpretations in response to shifting technologies and cultural standards. The introduction of the automobile, the rise of industry, zoning and building code innovations, and the information age have all had an influence on the design of cities.

The renewable energy revolution will also have a resounding influence on public space and landscapes in the coming decades. We are already starting to see the effects with the 21st century proliferation of wind turbines and solar farms.

Society can be resistant to change and to the introduction of new technology. That is why it is important that the new technologies evolve and become responsive to the sophisticated needs of the user (everyone who will be living with the new technologies in their daily lives).

Every day there is a new story about people disapproving of solar or wind installations in their communities. It’s not that they don’t care about the environment; in many cases the people opposing the installations are self-avowed environmentalists. To some people, the addition of turbines to the skyline that they can see from their porch or long stretches of dark blue panels in a field are forms of visual pollution. This is called the NIMBY (not in my backyard) response.

There is a real opportunity for interdisciplinary collaboration in design to soften the impact of renewable energy on our constructed environments and to help guide social acceptance of renewable energy infrastructure.

We live in a world that cross-culturally puts a high emphasis on design. Think about the objects in your home. Has anything been purchased because you and your family thought it was beautiful or well-designed?

Presenting the power plant as public artwork—simultaneously enhancing the environment, increasing livability, providing a venue for learning, and stimulating local economic development—is a way to address a variety of issues from the perspective of the ecologically concerned artist and designer.

**DIRECTIONS**

**AGES:** 15 +

**SUBJECTS:** Art, Science, Aesthetics, Engineering, Math, Sustainability, Design

**SUGGESTED TIME FRAME:** 1–2 hours

**PROCEDURE (SELF DIRECTED)**

1. Before you begin, read through the LEARN section of the information guide to get some important background inspiration.
2. When you are ready to begin, choose a flash card and read the questions on the front of it.
3. Use the information provided in the LEARN section to arrive at your answers.
4. Turn the card over. Was your answer correct?
5. Move on to another card of your choice and continue. Try to work out the answers for at least two cards.
6. As you explore the cards, you can refer back to the GLOSSARY section where you’ll find definitions of key terms.

7. This URL—www.landartgenerator.org/field-guide.pdf—will take you to A Field Guide to Renewable Energy Technologies, where you will find more information about different technologies that you can integrate into your design.

8. DESIGN YOUR OWN LAND ART GENERATOR! The last pages provide you with space to sketch your own ideas of what the future of energy can look like. Imagine some of the technologies that the other artists on these cards used. What other renewable energy technologies could you incorporate? Using tracing paper and a pencil or pen, sketch your ideas on top of the site plan and photo provided.

9. Email your designs to: energyart@landartgenerator.org

10. We will post your design in an online gallery for the world to see! Include your name and any other information you would like to share with us in the body of your email.

11. Within a few weeks you will find your design at www.landartgenerator.org/art+energy

OBJECTIVES
Examine and comprehend interdisciplinary information about public art and energy generation
Identify, describe, and analyze the ways in which electricity is generated and consumed
Learn about energy conservation
Learn about different types of energy generation technologies
Apply aesthetic decisions pertaining to color, line, and form in the conceptualization of new machines for energy generation
Understand the difference between peak capacity and productive output for different renewable energy technologies
Apply capacity factor to determine estimated annual outputs based on nameplate capacity

RECOMMENDED DISCUSSION QUESTIONS
• What types of renewable energy technologies have you seen at use in your community?
• What is the most interesting public art installation that you have visited?
• Are there ways in which you could conserve energy at home?
• What kind of renewable energy technologies do you find to be the most interesting to look at?

MATERIALS
tracing paper, pen or pencil

ASSESSMENT
Hang up all of the sketches on a wall space. Students share what technologies they chose and why. Engage in a discussion together about how the technologies chosen help to define the sculptural form of the different land art generator design ideas.

LEARN
PUBLIC ART
Public art encompasses any work of art that is created to be displayed, heard, or performed in a public space. Although the oldest and most common forms of public art are monuments, memorials, and statues, contemporary public art comprises a wide range of methodologies, forms, and content. Public art ranges in scope from large-scale, commissioned works that require significant collaboration amongst artists, funders, and governmental agencies to implement, to independently-executed small-scale works that require little to no funding. Public artworks may be site-specific, exhibited in non-conventional spaces or may alter the common function of a space. Because artworks
in the public sphere open up the possibility for community dialogue, they create dynamic and critical conversations that can help challenge conventional ways of viewing the world. Public artworks contribute to quality of life, public health, and the social cohesion of our cities.

Below is a list of artists whose work will inspire your creative energy. This is just a small sampling of artists working in public spaces and we encourage you to investigate further. Take a moment to do a little research online about their accomplishments. While you do, think about how it might be possible that public artworks can work towards enlivening public space while also generating clean and renewable energy. Do any of their concepts challenge the way you had previously thought about art?

Alice Aycock  Agnes Denes  Nancy Holt  Eve Mosher
Joseph Beuys  Andy Goldsworthy  Anish Kapoor  Robert Smithson
Betsy Damon  Antony Gormley  Maya Lin  Richard Serra
Walter De Maria  Sarah Hall  Len Lye

**FUNDAMENTALS**

Energy cannot be created or gotten rid of, but it can change its form. The form can be either potential (static at observable scale/position) or kinetic (dynamic/movement).

Its form can also be thermal, sonic, gravitational, chemical, nuclear, mechanical, elastic, magnetic, radiant, or electrical.

It can be measured in JOULES, CALORIES, BTUs, or KILOWATT-HOURS (these are all measures of the same thing much like inches and centimeters are both measures of distance). You may also see energy measured in barrels of oil equivalent (BOE), or cubic feet of natural gas equivalent, but these are approximations since the energy content of oil and gas can vary per volume based on many variables.

We can trace electrical energy (E) to the subatomic level where particles hold charges. We call them either positive or negative (a convention that has its origins in the work of Benjamin Franklin). We measure the strength of a charge in Columbs (C). A single electron has a “negative” charge of $1.6022 \times 10^{-19}$ Columbs.

When there is a charge in one object in relation to another object, this creates a potential difference in charge that we measure in Volts (V). It is this Voltage that causes the electrons to move from one object to the other in order to equalize the charges (correct the local imbalance). Electrical energy is equal to Columbs x Voltage ($E = CV$). A greater charge and/or a greater difference in charge between two objects create an increase in electrical energy. At this point it is still potential energy.

The actual flow (the kinetic form) of the electrons is known as Current and is measured in Amperes (I). Because it is a directional flow (one object to another differently charged object), it is measured over time (t). The amount of flow per quantity of time is Power (P), measured in the unit called watts.

This is important to understand because there is often confusion between measures of Power (watts) and measures of Energy (watt-hours).

Power (P) is a measure that can tell us the capacity of a system. It is equal to Voltage x Amperage ($P = VI$). It tells us both how much potential charge differential (V) and how strong a current (I) a particular system can accommodate. For example, an electrical system such as a toaster can safely function below its power rating or at that power rating, but if the power exceeds, it will lead to energy transfer in the form of heat. Raising either the Voltage or the Amperage will increase the Power. So if you have a 30 Ampere toaster that runs on a 110 Volt circuit (North American), it will draw 3,300 watts. If you plug that same toaster into a 240 Volt circuit (European), it will draw 7,200 watts and the circuit breaker will snap to disconnect the flow of energy, otherwise heat buildup could cause a fire.
The last thing to understand about basic electrical power is that conducting materials (that stuff which the electrons flow through, either copper wire or your body) are not perfect conductors. Along the way, some of the electrical energy is always lost to heat. This is Resistance (R) and it is measured in Ohms.

Thinking about water flowing through a hose is a good way to understand resistance. Assuming a constant water pressure (Voltage equivalent with electricity in the analogy), water will flow slower through a long hose than through a short hose. This is due to the friction in the hose, which offers resistance to the current. If you know Voltage (V) and Resistance (R), you can determine Current (I): I = V/R. A resistor in a circuit has a rating in Ohms (Ω) and is diagrammed with a zig-zag line.

Some useful relationships between the variables that we’ve discussed so far:

$$E = VC = VIt = Pt = V^2t/R = I^2Rt$$

Electrical Energy = Voltage x Charge = Voltage x Current x Time = Power x Time = (Voltage squared x Time)/Resistance = Current squared x Resistance x Time

$$P = VI$$

Watts = Volts x Amperes

**ENERGY CONVERSION**

While the total amount of energy can never be changed, energy can be transformed from different physically manifest forms. For example, thermal energy can be converted into mechanical energy through the processes that occur inside a steam turbine (water is heated up, which then creates pressure force that turns a rotor). That mechanical energy can then be converted into electrical energy by way of a dynamo (the rotational action spins a coil of conducting material within a magnetic field).

Scientists like Sir Charles Parsons and Michael Faraday discovered these conversion techniques by understanding the physical properties of materials, how they interact with each other, and how they change when heat energy is given to them.

Solar radiation energy can be converted directly into electrical energy with the use of semiconductors that display the “photovoltaic” effect (solar energy knocks off free electrons from the material). Nature has evolved photosynthesis to convert solar radiation energy into chemical energy.

When talking about electrical energy that is used for a purpose, like powering a house or a factory, we have to talk in terms of power over a period of time. That is why you will see the term “kilowatt-hour” (kWh) on your electric bill from the utility company. If you add up the individual watt ratings of all of your appliances, lights, etc. (everything with a wire running to it), you will find the peak demand load of your home (its capacity to use electricity).

This is measurable in watts. For example, say that you add everything up and it comes to 2,000 watts. If you turn everything on in your home and use it at its maximum setting for one hour you would find that you used about 2 kilowatt-hours of electrical energy.

The same is true for an energy generation system like a solar panel or a wind turbine. The rated (nameplate) capacity of the equipment is a function of how efficient the technology is at converting available natural energies into the electricity under ideal conditions. For example, a wind turbine is rated at 10 kilowatts (kWp). If it runs at peak (nameplate) capacity for one hour, then it would generate 10 kilowatt-hours (kWh).

**QUESTION**

A kWh is a form of measurement of energy. What other forms of measurement are there for Energy?
CONVERSION EFFICIENCY AND CAPACITY FACTOR

It is impossible to convert 100% of available natural energies into electrical power. There will always be inefficiencies in the process of conversion. These inefficiencies manifest in heat that escapes into the surrounding environment (waste energy) and also in energy that is deflected or bypasses the harvesting process. The goal for engineers designing renewable energy systems is to limit the amount of waste energy that is lost during the conversion process and ensure that the greatest amount of available energy is captured by the device.

When a design has been optimized for efficiency and a renewable energy product is ready to be sold and installed, it comes with a nameplate capacity, or a rated peak capacity. For example, a solar panel will typically receive 1000 watts of solar radiation on every square meter of its surface area during a sunny day. How many of those 1000 watts it is able to convert under ideal conditions (its conversion efficiency) defines its nameplate capacity. If a 1 m x 2 m panel is capable of converting 400 watts of solar power into electricity, then its conversion efficiency is 20% and its nameplate capacity is 400 watts. This is often expressed by the abbreviation “p” for “peak” as in 0.4 kWp.

Once the renewable energy-generating device is installed, there are other variables that will reduce the production of electricity. Perhaps the wind is not blowing or the sun is not out, or maybe the system has not been maintained very well and the parts are not functioning at their best. Due to these environmental factors, energy generation systems rarely function at their rated capacity (this is true of conventional fossil-fuel powered systems as well). The inefficiency due to these factors is referred to as the capacity factor. Following is a list of typical capacity factors for a number of different renewable energy technologies as measured over the course of a full year. These are only examples. The actual capacity factor for any installation will vary greatly depending on local conditions. We will refer back to these numbers in the exercises that follow. When calculating the output of any system using a capacity factor, you should use all 24 hours of a day even for solar power installations. Night hours are already figured into the capacity factor number.

RESIDENTIAL ELECTRICITY DEMAND

A large and inefficient single family house (one that keeps incandescent lights on all the time) will use about 10,000 kWh in a typical year (10 MWh per year, 833 kWh per month, 27.4 kWh per day). Efficient single family homes use far less — about 6 MWh per year. Smaller homes and apartments can use 3 MWh per year or less.

Actual use varies greatly depending on the time of day and the season of the year. While on average a house may only need 1.14 kilowatts of power to function for one hour, there may be times that this is higher (a hot summer day with cloud cover—you’ll need to cool the house and light it simultaneously), and other times that it is much lower (a nice spring night after everyone has gone to bed). The greatest amount that the house would require when functioning at full electrical capacity is known as its peak demand load.

DIG DEEPER

How many megawatt-hours does the average home in Denmark use every year? How about in the United States?

25% Onshore Wind
40% Offshore Wind
50–60% High Altitude Wind
27% Solar PV: Heliostatic (dual-axis sun tracking)
20% Solar PV: Fixed Angled
15% Solar PV: Fixed Horizontal
8% Solar PV: Fixed Vertical
30% Solar: CPV (heliostatic concentrated photovoltaic)
30–35% Solar Thermal CSP (concentrated solar power) without storage
40–70% Solar Thermal CSP (with integrated thermal storage)
ELECTRICITY DISTRIBUTION

Distribution is often discussed when it comes to renewable energy. This is because many of the best geographic locations for renewable energy generation are located far away from major city centers. One often cited example is the fact that the Saharan Desert in Northern Africa is the ideal location for large solar installations that could potentially power all of Europe and Africa.

Conventional high voltage energy transmission is limited by voltage drop along the lines (at each contact, conductor, and even along the line itself there is some level of resistance). Losses tend to be about 7% per 1,000 km for long distance high voltage alternating current overhead power lines. The higher the voltage, the less loss there is to resistance. This benefit from scale is maintained up to about 2000 kV (where other losses begin to take effect from corona discharge). High voltage lines tend to be in the range of 115 kV to 1200 kV depending on the length of the line (the voltage that reaches our homes is stepped down to the range of 120 V to 240 V).

The viable limit to high voltage alternating current electricity transmission is 7,000 km but the energy loss over such a distance is almost 50%. High voltage direct current (DC) is another option, which provides for losses of only 3% per 1,000 km. DC is more difficult to step up and down in voltage, but for high capacity over long distances DC transmission becomes worthwhile.

ALTERNATING CURRENT AND DIRECT CURRENT

The history of the relationship between alternating current (AC) and direct current (DC) begins at the end of the 19th century with the strong advocacy of the DC system by Thomas Edison, who at that time owned many of the patents for the DC equipment that dominated the electrical infrastructure.

For the most part, the DC system worked very well, with the one major limitation that electrical generation plants had to be located within about one mile (1.6km) of the destination of use (load). This is because the technology of the time did not allow for easy voltage stepping (DC transformers then were not very efficient), so the power had to be generated and transmitted at just slightly higher than the voltage of the intended load. If you wanted to power a light bulb at 100 V, then you produced and transmitted the power at 110 V just to allow for some transmission loss. And if you had multiple pieces of equipment that needed power at different voltages, you had to run completely separate lines to the source. While distributed generation was more democratic (allowing for energy cooperatives and limiting monopolization of power generation infrastructure), it was also fairly impractical.

By the mid-1890s, after the AC electrification of Rome, it was becoming clear to many, including George Westinghouse, that AC technology was more efficient for long distance transmission at higher voltages and with lower losses. Since that time, AC power has been the universal standard, but this may be about to change in the coming decades.

Interestingly, most digital consumer electronics today (transistors and LEDs) work on DC power, and these devices account for about 1/5 of electricity consumption in developed countries. Gregory Reed, director of the Power & Energy Initiative at the University of Pittsburgh, is one of those who is advocating for the efficiencies that can be gained by shifting to an all-DC infrastructure. With an increase in solar power generation (which is DC power), the exponential growth of computing power and data centers, and the impending electric car revolution, it makes sense to remove the AC transmission component entirely from distribution systems in which AC devices are the minority of end use equipment (each time electricity is converted from DC to AC and back again, there is power lost). With an aging infrastructure of AC equipment, the timing may now be perfect to reassess the benefits of DC. If only Edison was still around to witness it!
GLOSSARY

AEROLASTIC FLUTTER
A self-feeding regular vibration that occurs when wind passes by an object and stimulates the object’s natural frequency, creating a positive feedback loop. This often destructive effect is avoided in airplane wing and bridge engineering, but it can be intentionally utilized for wind energy power generation in combination with piezoelectrics.

AIRFOIL (AEROFOIL)
The shape of a wing in section as designed to provide lift and drag forces by creating positive and negative air pressure on opposite sides of the shape.

ALGAE BIOFUEL
Algae can be grown and harvested (algaculture) as a feedstock for the production of alternatives to fossil fuels. Naturally occurring oils within algae (lipids) can be used directly (similar to straight vegetable oil), or they can be refined to burn more cleanly. Different production methods can result in biodiesel, biobutanol, biogasoline, methane, ethanol, or even jet fuel. The uptake of CO₂ by the algae during cultivation offsets the CO₂ that is emitted during the combustion of the algae-generated fuel. Algae can produce up to 300 times more oil per acre than conventional crops such as jatropha, palm, rapeseed, or soybean, and it can be cultivated in locations where these types of crops are not viable.

ALTERNATING CURRENT (AC)
An electrical system in which the flow of electric charge periodically reverses direction (as opposed to direct current in which the flow is constant). AC was adopted early as the standard for electrical utility distribution due to the fact that transmission losses over great distances were less than with direct current (DC). Contemporary technology has made high voltage DC transmission (HVDC) the preferred solution for some long-distance distribution applications (lower transmission losses) but this requires changing the current from AC and back to AC on either end with expensive conversion equipment.

AMORPHOUS SILICON (A-SI)
The functioning semiconductor material within a type of photovoltaic system (thin film) that is less expensive and more versatile in its application than crystalline silicon types. Conversion efficiency is generally less than crystalline silicone PV. See “monocrystalline silicon” for more information.

BIOGAS AND BIOMASS
Biogas is created through the breakdown of any organic material (biomass) in an oxygen-poor environment. The resulting gas byproduct is mostly methane and carbon dioxide. Biogas is similar in composition to conventional natural gas and as such can be compressed or fed into a municipal gas grid. It can be used for many different purposes including cooking, heating, lighting, transportation, and electricity production. It can be either tapped from the underground activity in a landfill site, or it can be produced in specially constructed anaerobic digester tanks. Farms with such tanks can process manure into biogas reducing the amount of nitrous dioxide and methane that otherwise enter the atmosphere. These two gases have a far greater atmospheric warming effect than does carbon dioxide (nitrous dioxide = 310 times greater, and methane = 21 times greater). Biomass is considered a sustainable energy resource because it is a product of organic processes, which naturally regenerate at a rapid cycle (as opposed to fossil fuel energy sources which take millions of years to form naturally). Biomass can be combusted directly as a solid fuel or converted to liquid or gas biofuels. These biofuels can be used in either a combustion engine (conversion to mechanical energy) or in a fuel cell (conversion to electrical energy).
CAPACITY FACTOR
A multiplier used to calculate the average output of an energy-generating device over a certain period of time. This factor takes into account conditions that are less than ideal and which contribute to the device operating at below nameplate capacity during certain periods. See “nameplate capacity” for more information.

CARBON DIOXIDE (CO₂)
A naturally occurring chemical compound critical to life on earth, carbon dioxide also functions as a greenhouse gas in the Earth’s atmosphere. The emission of CO₂ through fossil fuel combustion by humans has, since modern industrialization, created an increase of 35% in the parts per million (ppm) concentration of the gas in the Earth’s atmosphere. Since 1960, its concentration has risen from 320ppm to 390ppm and further increases threaten rapid shifts upward in global temperature and sea levels. In order to avoid a temperature rise beyond 2°C Celsius, between 2/3 and 4/5 of the known reserves of fossil fuel will need to remain unused until such time that proven methods of carbon capture and storage (CCS) can allow their safe combustion (no method of CCS has yet been proven suitable for long-term CO₂ storage). Increased atmospheric concentrations of CO₂ also have a secondary effect on the chemical composition of the oceans, as surface-level carbon dioxide dissolves forming other carbon compounds and leading to acidification.

COMPACT WIND ACCELERATION TURBINE (CWAT)
CWATs are a new acronym that encompasses the class of machines formerly known as DAWTs as they were known in the 1970s and 1980s. This type of horizontal axis wind turbine uses a cone or series of cones to concentrate the wind, increase the velocity of the wind as it passes through the rotor’s swept area, and thus increase the efficiency of the overall system. They are also known as “ducted turbines” or “lens wind turbines.”

CONCENTRATED SOLAR POWER
Describes a variety of systems that use mirrors or lenses to concentrate the power of the sun in order to create heat energy that can then be converted into electricity.

CONVECTION LOOP
In the dynamics of fluids or gas, the tendency of higher pressure and lower pressure to equalize causes warm to migrate towards cool, thus creating a flow of gas or liquid. In closed systems with heat input in one area, a continuous loop is created as warm material flows to cool areas.

COPPER INDIUM GALLIUM SELENIDE (CIGS)
A semiconductor material alternative to silicon used in thin film photovoltaic.

DATA MONITORING
Real-time statistics of how much electricity is being produced. Monitoring can be either on site or remotely accessed and is displayed in an easy-to-understand graphical interface that often simulates analog dials and meters.

DIRECT CURRENT (DC)
An electrical system in which the flow of electric charge is constant (as opposed to alternating current in which the flow periodically reverses direction). See “alternating current” for more information.

DYE-SENSITIZED SOLAR CELL (DSSC)
Techniques for creating dye-sensitized solar cells (DSSC) are simple and the materials are very low cost, but the conversion efficiency is also below that of solid-state semiconductor technologies (DSSC is the most efficient of the “third generation” thin films). This technique was invented in 1991 by Michael Grätzel and Brian O’Regan at EPFL. The DSSC solar cell is alternatively known as the Grätzel cell. They have the characteristic of being semi-transparent, flexible, and they are very durable. They also function comparatively better than other PV technologies in low light levels and indirect light. Because they are so inexpensive to produce they have one of the lowest price/performance ratios, and are therefore potentially competitive with conventional energy in terms of levelized cost ($ per kWh over the lifetime of the installation) despite their lower conversion efficiency.
ELECTRODE
The electrical conductor that makes contact with a semiconductor or other non-metallic material. Electrodes can be labeled either anode or cathode depending on which direction the electrical charge is flowing.

ELECTROSTATIC
Having to do with the build-up or the discharge of static electricity usually through the triboelectric effect where a material passes electrons to another material through physical contact.

EFFICIENCY (ENERGY CONVERSION EFFICIENCY TO ELECTRICITY)
The ratio between the electrical output of a device (such as a solar panel or a wind turbine) and the energy input to the device (the sun or the wind that strikes the device). The efficiency of any device determines its nameplate capacity. See “nameplate capacity” and “capacity factor” for more information.

FEEDSTOCK
In power generation this refers to the source of the energy as it exists in non-electrical form. This could be chemical energy (petroleum and biofuel), radiant or thermal energy (solar), or gravitational (hydro), or mechanical (wind and wave).

FRESNEL LENS
A magnifying lens that takes the sectional geometry of a simple convex lens and flattens it by slicing it in concentric circles and shifting the sliced segment profiles to create a flattened, corrugated surface. The optical effect of the lens is very similar to that of the original convex lens. Fresnel lenses are used in many concentrated photovoltaic systems to focus the sun’s energy onto specially engineered photovoltaic cells.

FUEL CELL
Any mechanical system that converts the energy stored within a fuel source (e.g. hydrogen, methanol) into electricity through an oxidation process. Fuel cells require the replenishment of the fuel source (reactant) to maintain electrical output. Fuel cell technology has the potential to replace the internal combustion engine for the conversion of fuel into energy for use in transportation and machinery.

HELIOTROPIC (HELIOSTATIC)
The ability to follow the location of the sun in the sky and maintain an object’s consistent relationship to it throughout the diurnal and seasonal shift. In solar energy technology, heliostatic mechanisms can maintain a solar cell perpendicular to the sunlight for ideal absorption and conversion, or mirrors can maintain an angle-of-incidence relationship to the sun so as to consistently reflect sunlight to a central collector.

HIGH-ALTITUDE WIND POWER (HAWP)
The power of the wind at high altitudes is much stronger and more consistent than what is typically available nearer to the ground. However, getting access to this excellent source of energy and harnessing it for electrical use presents obvious challenges. HAWP has the potential to be a cheap and consistent source of energy. There are a wide number of technologies that are presently being developed. Many designs are derivative of kite and sailing technology. Other types of HAWP devices (airborne turbines, or AWT) use light-than-air balloons (aerostats) that rotate between two cables, or small glider-like machines that are designed to fly in a constant circle or figure-eight. In these technologies the conversion of energy to electricity is performed in the sky.

HYDROELECTRIC STORAGE
Excess capacity electricity is used to pump water temporarily into an upstream reservoir. The water can then later be released when there is demand for electricity and by the force of gravity drives hydraulic turbine electrical generators similarly to conventional hydroelectric dams which rely on natural precipitation cycles to provide the water source.
HYDRAULIC TURBINE
A rotary engine that is driven by the force of passing water.

HYGROELECTRICITY
Hygroelectricity is naturally present in the air as a type of static electricity due to the difference in charge between water droplets and dust particles. A build-up of hygroelectric charge can sometimes lead to lightning. It has been proposed (originally by Nicola Tesla, and more recently by Brazilian researchers Telma R. D. Ducati, Luis H. Simoes, and Fernando Galembeck) that this static electricity could be harnessed and transformed into usable electrical current.

KILOWATT (KW)
Equal to 1,000 watts. See “watt.”

KILOWATT-HOUR (kWh)
Equal to 1,000 watt-hours. See “watt-hour.”

KITE WIND POWER OR WIND KITE
See high-altitude wind power (HAWP).

LED
Light-emitting diode, a semiconductor light source. OLED is an LED made from organic compounds.

LINEAR ALTERNATOR
A linear motor used as a power generator for alternating current. Linear motors do not rely on torque and rotation but rather on simple linear motion.

MEGAWATT (MW)
Equal to 1,000,000 watts. See “watt.”

MEGAWATT-HOUR (MWh)
Equal to 1,000,000 watt-hours. See “watt-hour.”

MONOCRYSTALLINE SILICON
Silicon (Si) is a semiconductor material that displays the photovoltaic effect. It was the first material to be employed in solar cells and is still the most prevalent. It can be applied for use in either a crystalline (wafer) form, or in a non-crystalline (amorphous) form. There are two types of crystalline silicon: monocrystalline and polycrystalline (aka multicrystalline). Monocrystalline is very expensive to manufacture (because it requires cutting slices from cylindrical ingots of silicon crystals that are grown with the Czochralski process) but it is the most efficient crystalline silicon technology. Its conversion efficiency is around 23%.

NAMEPLATE CAPACITY
The standard and consistent power that an energy-generating device can output in an ideal environment.

OMNI-DIRECTIONAL PHOTOVOLTAIC
Able to convert sunlight into electricity at any angle in relation to the sun. Most PV technologies either require or work best at an angle perpendicular to the sun’s position in the sky.

ORGANIC PHOTOVOLTAIC
Organic PV can be manufactured in solutions that can be painted or rolled onto proper substrate materials. They can be produced at very low cost in comparison with other PV technologies because they can take advantage of roll-to-roll production techniques in which the organic photovoltaic system is “printed” onto a long continuous sheet of substrate material. Current OPV technology has a conversion efficiency of only around 8%. But its low cost of production (and its good performance in lower level and indirect light) makes it an increasingly attractive option in the marketplace.
PARABOLIC TROUGH
A type of concentrated solar power that uses a long mirrored surface with the cross-sectional shape of a parabola. Sunlight that hits the mirror surface (at an angle parallel to the central axis of the parabola) is directed to the focal point of the parabola thus providing energy to a heat transfer fluid that runs continuously along its length. The heated transfer fluid can be used to generate the steam required for turbine generators.

PARAFOIL
A nonrigid airfoil typically constructed out of ripstop nylon, with an aerodynamic cell structure that is inflated by the wind. The parafoil is forced into a wing cross-section through ram-air inflation.

PARAGlider
A type of small gliding aircraft usually launched by foot.

PARAKITE
A series of kites on one string designed to fly in tandem, or one of such kites within the series.

PEAK CAPACITY
The highest design output that an energy-generating device can manage under ideal conditions and newly installed components.

PHOTOVOLTAIC (PV)
The photovoltaic effect, first recognized by A. E. Becquerel in 1839, is the ability of a material to produce direct current electricity when exposed to solar radiation. It is related to the photoelectric effect, which is the ejection of an electron from a material substance (usually a more highly conductive metal as opposed to a semiconductor material) by electromagnetic radiation incident on that substance. However, in the photovoltaic effect, the electrons remain within the material (by the nature of the semiconductor material) creating positive and negative bands which can be harnessed by an electrical circuit.

PHOTOVOLTAIC OPTICAL FIBER
The use of optical fiber to channel sunlight onto photovoltaic cells, typically dye-sensitized solar cells (DSSC) which are able to be applied to flexible surfaces.

PIEZOELECTRIC GENERATOR
A device that generates electrical power from pressure force. Common application of a piezoelectric device is as the ignition source for gas range and grill “push starters.”

PNEUMATIC CONDENSER
A device used to compress air or other inert gas.

PNEUMATIC MEMBRANE
A membrane that can be inflated. PTFE-coated glass fiber fabric and ETFE foil can be used to create permanent membrane structures.

RECIPIROCATING
Operating with a repetitive back-and-forth or up-and-down linear motion.

SEMITRANSPARENT PHOTOVOLTAICS
Solar cells that are encased in a transparent material in such a way that allows light to pass through partially. The pattern of the photovoltaic material placement can be small or large, patterned or irregular.

SMART GLASS
Glass that is capable of changing its transparency when voltage is applied.
**SOLAR FABRIC**
Flexible photovoltaic material integrated into canvas.

**SOLAR THERMAL**
Solar radiation used to heat a medium such as water or air.

**SOLAR UPDRAFT (SOLAR CHIMNEY)**
Combines the chimney/stack effect and greenhouse effect with wind turbines located at the base of a very tall tower. The tower is surrounded by a large greenhouse which serves to create superheated air at the ground level. With a sufficiently tall chimney structure, the air temperature at the top of the tower will be cool enough to provide a strong convection movement of air from the greenhouse area, into the bottom of the chimney and out of the top of the chimney (warmer air is higher pressure and moves to the lower pressure system at the top of the tower). At the outside perimeter of the greenhouse, new surface air is constantly taken into the system to be heated. As air passes from the greenhouse area into the base of the tower, it powers wind turbines located there.

**STIRLING HEAT ENGINE**
Device that converts heat into mechanical energy with high efficiency. This mechanical energy can then be used to power an electrical generator.

**TENSEGRITY**
Individual structural members (usually metal bars) working in compression are suspended away from each other by means of a continuous tension net (usually comprised of metal cables). The term was coined by Buckminster Fuller as a portmanteau of “tensional” and “integrity.” The structural system has been used in many works of public art, including those by Kenneth Snelson.

**THERMOACOUSTIC ENGINE**
A device that uses heat differentials to generate sound waves or, in reverse operation, uses sound wave energy to transfer heat.

**THIN FILM**
As applied to photovoltaics, any of a variety of non-crystalline solar cell technologies that can be applied in very thin layers thus reducing material costs.

**THIRD-GENERATION PHOTOVOLTAIC**
Term applied to technological innovations that have allowed conversion efficiencies of solar cells to increase greatly via tandem or multi-junction structures that have varying bandgaps (physical property of the material that pertains to the flow of electrons through it or from it under conditions of excitation such as that provided by solar radiation). In single junction solar cells, there is energy lost when photoexcitation exceeds the limits of the particular semiconductor’s bandgap.

**TURBINE ROTOR**
The moving part of a turbine engine which consists of a drum or a shaft with blades attached to it.

**UTILITY-SCALE**
Significant enough power generation so as to warrant the distribution of the energy to the utility grid (as opposed to “on-site” power generation for local use).

**VENTURI EFFECT**
When a fluid body, such as air, is in motion and is constricted in its path, such as by a funnel, the velocity of the fluid will increase and its static pressure will be reduced. The effect can be felt in urban areas when standing between two tall buildings, which together act as a funnel. This principle is incorporated into the design of compact wind acceleration turbines (CWAT).
**VERTICAL-AXIS WIND TURBINE**
Any wind turbine in which the rotational axis is vertical in orientation (perpendicular to the ground plane). Types of vertical-axis wind turbines include Savonius, Darrieus (egg-beater), and Giromills.

**WASTE TO ENERGY (WtE)**
The use of non-recyclable waste for combustion (incineration) to generate electricity, or in a small number of cases for processing into methane or similar fuel.

There are some emerging WtE technologies that do not require incineration:
- Gasification (produces hydrogen, synthetic fuels)
- Thermal depolymerization (produces synthetic crude oil)
- Pyrolysis (produces combustible tar, bio-oil, and biochars)
- Plasma arc gasification, PGP (produces syngas)

Non-thermal technologies:
- Anaerobic digestion (biogas rich in methane)
- Fermentation production (ethanol, lactic acid, hydrogen)
- Mechanical biological treatment (MBT)

Limestone scrubbers can greatly reduce the emission of harmful chemicals from WtE incineration, and while there is CO₂ released, the effect of this is less than the more toxic greenhouse gases that are produced by landfill off-gassing of methane, even if much of that methane is captured.

**WATER-SOURCE HEAT SINK LOOP**
A geothermal or ground-source heat pump operating in a cooling capacity. Water is passed via coiled tubing through the earth (which maintains a constant temperature between 10°C Celsius and 16°C Celsius depending on latitude) and then used for cooling interior space via a heat exchanger.

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**WATT (W)**
Unit of measure of electrical power equivalent to 1/746 horsepower.

W = Volts x Amperes

**WATT-HOUR**
A measure of electrical energy equivalent to one watt of power used or produced for a one-hour duration.

**WIND MICROTURBINE**
A small wind turbine with less than 3,000 watt peak capacity.

**WINDROSE**
A graphic representation of the wind at any one location as measured over a long period of time. The windrose diagram shows the frequency of wind speed and cardinal direction that the wind is blowing from.

**WIND TURBINE**
A rotary engine driven by the force of passing wind that can convert rotational force into electrical power.
**INDLEDNING**

**NYTTIGE OPLYSNINGER FOR DU BEGYNDER AT BRUGE DISSE KORT**

De vedlagte kort vedrører både videnskab, teknologi, teknik, design og kunst. Billederne på forside af hvert kort repræsenterer ideer bag store offentlige kunstprojekter i det offentlige rum, der genererer ren energi til vores byer. Disse kunstneriske kraftværker er designet til at være sikre for det naturlige miljø, til ikke at producere forurening, til at generere energi til op til tusindvis af hjem og til at gøre vores offentlige rum mere spændende. Nogle af dem har ekstra fordele i form af spiselige haver, levesteder for dyr, luftfiltrering, datavisualisering og rekreationsområder.

En ubegrænset mængde teknologier og materialer kan indlemmes i Land Art Generators. Og de anvender alle en række metoder til udvinding af energi fra naturlige ressourcer som solen, vinden, biokemi og kinetisk bevægelse.

Når du bruger disse kort kan du tænke over, hvordan dit design ville se ud som et energigenererende kunstværk! Hvilke teknologier ville du bruge? Hvor mange hjem kunne det forsyne med strøm?

**SÅDAN DEFINERES ELEKTRISK STRØM**

**HVAD ER EN WATT?**
Måleenhed for elektrisk strøm, der svarer til 1/746 hestekræfter

**HVAD ER EN WATT-TIME?**
En elektrisk energienhed, der svarer til en watt strøm, der anvendes eller produceres konstant i løbet af en time

**HVAD ER EN KILOWATT (kW)?**
Svarer til 1.000 watt

**HVAD ER EN KILOWATT-TIME (kWh)?**
Lig med 1.000 watt-timer eller en kW effekt eller forbrug i løbet af en time

**HVAD ER EN MEGAWATT-TIME (MWh)?**
En megawatt-time er en million watt leveret kontinuerligt i løbet af en time

**HVORFOR ER ELEKTRICITET VIGTIG?**

Elektricitet er blot en af mange former, som energi kan tage (andre omfatter termisk, kemisk og mekanisk), men dener en af de mest alsidige og nyttige, og består af omkring 40 % af den samlede energi, der forbruges af mennesker.

Vi vil med disse øvelsers formål for øje fokusere på elektrisk energi og på måder hvormed vi kan reducere vores elektricitetsforbrug og begrænse mængden af drivhusgasemissioner som productionen af elektricitet genererer. Produktionen af elektricitet fra fossile brændsler bidrager til globale klimaændringer via drivhusgasemissioner (som kuldioxid, kulilte, methan og andet), som lukker solvarmen inde i jordens atmosfære.

FN’s klimapanel “The International Panel on Climate Change” (IPCC) har konkluderet, at vi allerede har passeret det punkt, hvor kvantiteten af de drivhusemissioner, der allerede befinder sig i vores atmosfære, vil forårsage, at den globale middeltemperatur i det 21. århundrede stiger med 2°C, og at den kan stige til 4°C eller helt op til 6°C, hvis vi ikke ophører med at bruge fossile brændsler. De menneskelige konsekvenser af denne type hurtige ændring i vores økosystems skrøbelige balance er ekstreme, som selv ved en stigning på 2°C omfatter evakuering af enorme menneskemængder, en stigning i sygelighed, mad og vandmangler, og en stigning i ekstreme vejrfænomener. Det er derfor ekstremt vigtigt, at vi arbejder sammen for at reducere vores afhængighed af fossile brændsler som vores energikilde så hurtigt som muligt.

Bygninger er ansvarlige for 65 % af elektricitetsforbruget (omkring halvdelen er privatboliger), så vi vil komme langt i reduktionen af drivhusgasser ved at reducere vores private elektricitetsforbrug. Og hvis vi kan erståtte kulfyrede og gasfyrede kraftværker med produktion af ren og vedvarende elektricitet i løbet af de næste årter, er vi muligvis i stand til at standse stigningen af middeltemperaturen til under 3°C, og afværge de værste påvirkninger af globale klimaændringer.
**OFFENTLIG ANERKENDELSE AF VEDVARENDE ENERGI**

Teknologien, der gør det muligt at foretage omstillingen fra fossile brændsler til vedvarende energi, eksisterer allerede. Videnskabsmand og ingeniører har i de sidste årter arbejdet på at gøre vedvarende energi billigere og mere pålidelig, og vi er nu nået til det punkt, hvor den samlede pris på at generere elektricitet fra ikke-forurenende, vedvarende energikilder, er lig med prisen på at gøre det med kul og olie. Udfordringen er nu at overbevise en række mennesker om at stå bag ændringen, da det kræver en kolossal samlet indsats og en ændring af vores nuværende systemer og økonomier.

Den vedvarende energirevolution vil også have en rungende indvirkning på offentlige rum og landskaber i de komende årter. Vi ser allerede virkningerne her i det 21. århundrede i form af den hastige vækst af vindmøller og solpaneler.

Vores samfund kan have en tendens til at være imod ændringer og ny teknologi. Derfor er det vigtigt, at den nye teknologi i sig selv udvikler sig og reagerer på brugerens sofistikerede behov (alle dem, der kommer til at leve med de nye teknologier i deres hverdag).

Via tværfaglige designsamarbejder er der en oplagt mulighed, for at mildne udtrykket i vedvarende energi generatører i vores nærmiljøer, og samtidig hjælpe med at guide social accept af infrastrukturen i forbindelse med den vedvarende energi.

Hver dag er der en ny historie om folk, som er imod sol- eller vindinstallationer i deres lokalsamfund. Det er ikke fordi, de er ligeglade med miljøet; i mange tilfælde er de mennesker, der er modstandere af installationerne, selvudrøbte miljøtilhængere. For nogle er opsætning af vindmøller i horisonten, som de kan se fra deres terrasse eller lange rækker af mørkeblå solpaneler i en mark en form for visuel forurening. Denne reaktion kaldes “NIMBY” (not in my backyard), ikke i min baghave.

Vi lever i en verden, som på tværs af alle kulturer fremhæver design. Tænk på tingene i dit hjem. Har du og din familie købt noget, fordi I syntes, det var smukt eller godt designet?

**ANVISNINGER**

**ALDER:** 15 +

**EMNER:** Kunst, Videnskab, Æstetik, Teknik, Matematik, Bæredygtighed, Design

**ANBEFALET TIDSRAMME:** 1–2 timer

**FREMGANGSMÅDE (SELVSTUDIE)**

1. Før du begynder, bedes du læse pakkens afsnit LÆR for at få vigtig baggrundsinspiration.
2. Når du er klar til at begynde, vælger du et flashkort og kigger på spørgsmålene foran på kortet.
3. Brug informationen i afsnittet LÆR til at besvare spørgsmålene foran på kortet.
4. Vend kortet om. Var dit svar korrekt?
5. Gå videre med endnu et kort efter eget valg og fortsæt. Forsøg at finde frem til svarene på mindst to kort.

Efterhånden som energiforsyningsenhederne kommer tættere på de privatboliger, som de forsyner, kommer æstetikken i højtænde i de mange debatter om emnet. Bymiljøet har igennem historien undergået fortsatte genfortolkninger af design som respons på skiftende teknologier og kulturelle standarder. Bilens komse, den industrielle revolution, zoneinddeling og bygningskodeinnovationer samt informationsalderen har alt sammen haft en indvirkning på byers udformning.

Når vi nu præsenterer kraftværker som offentlige kunstværker — og samtidig forbedrer miljøet, øger samfundets livskvalitet, skaber et sted for læring og stimulerer den lokale, økonomiske udvikling — er det en måde at adressere en række problemer på fra den økologisk interesserede kunster og designers synspunkt.
Mål
Undersøg og forstå interdisciplinært information om offentlig kunst og energiproduktion
Identificér, beskriv og analyser hvordan elektricitet genereres og forbruges
Lær om energibesparelse
Lær om forskellige typer energiproduktionsteknologier
Træf æstetiske beslutninger vedrørende farve, linje og form i konceptualiseringen af nye maskiner til energiproduktion
Forstå forskellen mellem spidskapacitet og ydelse for forskellige vedvarende energiteknologier
Brug kapacitetsfaktoren til at bestemme de skønnede årlige ydelser baseret på spidskapacitet

Anbefalede diskussionsspørgsmål
- Hvilke typer vedvarende energiteknologier har du set anvendt i dit lokalsamfund?
- Hvad er den mest interessante offentlige kunstinstallation, du har set?
- Er der måder, hvorpå du kan spare energi i hjemmet?
- Hvilke slags vedvarende energiteknologier synes du er mest interessante at se på?

Materialer
tegnepergament, kuglepen eller blyant

Vurdering
Hæng alle tegninger op på væggen. De studerende fortæller, hvilke teknologier de valgte og hvorfor. Tag en diskussion sammen om hvordan de valgte teknologier hjælper med at definere den skulpturelle form på de forskellige land art generator-designideer.

Lær
Offentlig kunst omfatter alle kunstværker, der er blevet skabt til at blive vist, hørt eller udført i et offentligt rum. Selvom de ældste og mest almindelige former for offentlig kunst er monumenter, mindesmærker og statuer, omfatter moderne kunst i det offentlige rum en lang række metodologier, former og indhold. Offentlig kunst spænder over store bestillingsværker, som kræver signifikant samarbejde mellem kunstnere, bidragsydere og myndigheder om implementeringen til uafhængigt udførte små værker, der kun kræver en smule eller ingen finansiering. Offentlige kunstværker kan være stedspecifikke, kan være udstillet på ukonventionelle steder eller kan ændre et steds normale funktion. Fordi kunstværker i den offentlige sfære åbner for muligheden for dialog i samfundet skaber de
dynamiske og kritiske samtaler, der kan hjælpe os med at udfordre de konventionelle måder, vi anskuer verden på. Offentlige kunstværker bidrager til livskvalitet, folkesundhed og social sammenhængskraft i vores byer.

Nedenfor er en liste over kunstnere, hvis arbejde vil inspirere din kreative energi. Tag et øjeblik nu og udforsk deres arbejder. Dette er blot et lille udsnit af kunstnere, der arbejder i det offentlige rum, og vi opfordrer dig til at udforske yderligere. Mens du gør det kan du tænke over, hvordan kunstværkerne i det offentlige rum både kan nå målet med at gøre det offentlige rum mere levende og producere ren og vedvarende energi. Udfordrede nogle af deres koncepter den måde, som du tidligere har betragtet kunst på?

Alice Aycock  Agnes Denes  Nancy Holt  Eve Mosher
Joseph Beuys  Andy Goldsworthy  Anish Kapoor  Robert Smithson
Betsy Damon  Antony Gormley  Maya Lin  Richard Serra
Walter De Maria  Sarah Hall  Len Lye  GRUNDLIGGENDE PRINCIPPER

Man kan ikke skabe energi eller få den til at forsvinde, men den kan ændre form. Formen kan enten være potentiell (statiskt/beliggenhedsenergi) eller kinetisk (dynamisk/bevægelse).

Dens form kan også være termisk, sonisk, tyngdekraftsmæssig, kemisk, kernemæssig mekanisk, elastisk, magnetisk, strålingsmæssig eller elektrisk.

Den kan måles i JOULES, KALORIER, BTUs eller KILOWATT-TIMER (disse er alle målinger af det samme, ligesom tommer og centimeter, der begge er afstandsmålinger). Du kan også se energi målt i tønder olie (BOE) eller kubikfod naturgas, men disse er tilnærmelsesværdier, da energiindholdet af olie og gas kan variere pr. mængde baseret på mange variabler.

Vi kan spore elektrisk energi (E) til det subatomiske niveau, hvor partiklerne er ladede. Vi koster der enten positive eller negative (en konvention, der har sin oprindelse i Benjamin Franklins arbejde). Vi måler styrken af en ladning i Coulombs (C).

En enkelt elektron har en ”negativ” ladning på 1,6022x10^-19 Coulombs.

Når der er en ladning i et objekt i forhold til et andet objekt, skaber dette en potentiel forskel i ladningen, som vi måler i Volt (V). Det er denne spænding, der får elektronerne til at bevæge sig fra et objekt til et andet for at udlignie ladningerne (korrigerer den lokale ubalance). Elektrisk energi er lig med Coulombs x spænding (E = CV). En større ladning og/eller en større forskel i ladningen mellem to objekter skaber en stigning i elektrisk energi. På dette punkt er det stadig potentiel energi.

Elektronernes faktiske gennemstrømning (den kinetiske form) kaldes strøm og måles i ampere (I). Da det er en direktionel gennemstrømning (et objekt til et andet anderledes ladet objekt), måles den over tid (t). Gennemstrømningsmængden pr. tidskvantitet er effekt (P), målt i enheden, der kaldes watt.

Dette er vigtigt at forstå, da der ofte opstår forvirring mellem måleenhederne for effekt (watt) og energi (watt-timer).

Den sidste ting, der er vigtigt at forstå om grundlæggende elektrisk strøm er, at ledende materialer (de genstande, som elektronerne strømmer igennem, enten kobbertråd eller din krop) ikke er perfekte strømledere. Under forløbet tabes noget af den elektriske energi altid til varmen. Dette er modstand (R) og måles i ohm.

En god måde at forstå modstand på er at tænke på vand, der strømmer gennem en slange. Hvis man forestiller sig et konstant vandtryk (spænding lig med elektricitet i analogien) vil vandet strømme langsommere gennem en lang slange end en kort slange. Dette sker på grund af friktionen i slangen, som mindsker strømmens kraft. Hvis du kender spænding (V) og modstand (R) kan du bestemme strømmen (I): I = V/R. En resistor i et kredsløb har en nominel effekt i ohm (Ω) og er afbildet med en zigzaglinje.

Visse nyttige forhold mellem variablene, som vi indtil videre har drøftet:

\[ E = VC = Vi = Pt = VIt = P \times t = \frac{V^2}{R} = \frac{I^2}{R}t \]

Elektrisk energi = spænding x ladning = spænding x strøm x tid = effekt x tid = (spænding i anden potens x tid)/modstand = strøm i anden potens x modstand x tid

\[ P = VI \]

Watt = Volt x Ampere

**SPØRGSMÅL**

En kWh er en form for måling af energi. Hvilke andre former for målinger er der for energi?

**ENERGIKONVERTERING**

Mens den samlede mængde energi aldrig kan ændres, kan energien omdannes til forskellige fysiske former. For eksempel kan termisk energi konverteres til mekanisk energi gennem processerne, der opstår inden i en damp turbine (vand varmes op, som så danner en trykkraft, der får en rotor til at dreje rundt). Den mekaniske energi kan dernæst konverteres til elektrisk energi via en dynamo (drejemekanismen drejer en spole af ledende materiale i et magnetisk felt).

Videnskabsmænd som Sir Charles Parsons og Michale Faraday opdagede disse konversionsteknikker ved at forstå materialernes fysiske egenskaber, hvordan de interagerer med hinanden og hvordan de ændrer sig, når de får varmeenergi.

Sølenergi kan konverteres direkte til elektrisk energi ved anvendelse af halvledere, der viser den "fotovoltaiske" effekt (sølenergi banker frie elektroner af materialet). Naturen har udviklet fotosyntese således, at den konverterer sølenergien til kemisk energi.

Når vi taler om elektrisk energi, der anvendes til et formål, som forsyning af hus eller en fabrik med strøm, bliver vi nødt til at tale i begreber som effekt over en tidsperiode, hvilket forklarer begrebet kilowatt-time (kWh), som figurerer på din elektricitetsregning fra elselokket. Du kan finde ud af kapaciteten, som dit hus har til at bruge energi ved at lægge alle watt-effekterne sammen fra alle dine apparater, lys osv. (alt, der har en ledning).

Dette kan måles i watt. Lad os for eksempel sige, at du lægger alting sammen, og det bliver 2.000 watt. Hvis du tænder for alt og bruger tingene på deres maksimale indstilling i en time, vil du se, at du har brugt omkring 2 kilowatt-timer elektrisk energi.

Det samme gælder for et energiproduktionssystem som et solpanel eller en vindmølle. Udstyrets spidskapacitet er en funktion af hvor effektiv teknologien er til at konvertere tilgængelige, naturlige energier til elektricitet under ideelle forhold. For eksempel er en vindmølles nominelle effekt 10 kilowatt (kWp). Hvis den kørte ved spidskapacitet i en time, ville den producere 10 kilowatt-timer elektrisk energi.
**OMDANNELSESVIRKNINGSGRAD OG KAPACITETSFAKTOR**

Det er umuligt at konvertere tilgængelige, naturlige energier til elektrisk effekt 100 %. Der vil altid være en vis ineffektivitet i konverteringsprocessen. Disse ineffektiviteter manifesteres i varme, der slipper ud i det omgivende miljø (affaldsenergi) og også i energi, der deflekteres eller omgår høstningsprocessen. Målet for ingeniørerne, der designer vedvarende energisystemer, er at begrænse mængden af affaldsenergi, der går tabt under konverteringsprocessen og sikre, at den størst mulige mængde energi indfanges af enheden.

Når et design er blevet optimeret for effektivitet og et vedvarende energiprodukt er klar til at blive solgt og installeret, ledsages den af en fuldlastkapacitet eller en nominel spidskapacitet. For eksempel vil et solpanel typisk modtage 1000 watt solstråling på hver kvadratmeter af dens overfladeareal på en solskinsdag. Hvor mange af disse 1000 watt, det kan konvertere under ideelle forhold (dets omdannelsesvirkningsgrad) definerer dets spidskapacitet. Hvis et panel på 1 m x 2 m er i stand til at konvertere 400 watt solkraft til elektricitet, er dets omdannelsesvirkningsgrad 20 % og dets spidskapacitet 400 watt. Dette udtrykkes ofte med forkortelsen ”p” for “peak” (spids) som i 0,4 kWp.


<table>
<thead>
<tr>
<th>Kapacitetsfaktor</th>
<th>Eksempler</th>
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</thead>
<tbody>
<tr>
<td>25 % Vind på land</td>
<td>20 % Sol-PV: Fastvinklet</td>
</tr>
<tr>
<td>40 % Vind på hav</td>
<td>15 % Sol-PV: Fast vandret</td>
</tr>
<tr>
<td>50–60 % Vind højt over havoverfladen</td>
<td>8 % Sol-PV: Fast lodret</td>
</tr>
<tr>
<td>27 % Sol-PV: Heliostatisk (dobbeltakset soltracker)</td>
<td>30 % Sol: CPV (heliostatisk koncentreret fotovoltaik)</td>
</tr>
<tr>
<td>20 % Sol-PV: Fastvinklet</td>
<td>30–35 % Soltermisk CSP (koncentreret solkraft) uden lagring</td>
</tr>
<tr>
<td>15 % Sol-PV: Fast vandret</td>
<td>40–70 % Soltermisk CSP (med integreret termisk lagring)</td>
</tr>
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**ELEKTRICITETSBEHOV I BOLIGER**

Et stort og ineffektivt enfamilieshus (et, der lader lysene brænde hele tiden) bruger ca. 10.000 kWh på et typisk år (10 MWh pr. år, 833 kWh pr. måned, 27,4 kW h pr. dag). Effektive enfamilieshuse anvender langt mindre — omkring 6 MWh pr. år. Mindre huse og lejligheder kan anvende 3 MWh pr. år eller mindre.

Faktisk anvendelse varierer meget, afhængig af tiden på dagen og årstiden. Mens et hus gennemsnitligt kun har brug for 1,14 kilowatt-strøm for at kunne fungere i en time, kan der være tidspunkter, hvor behovet er større (en varm sommerdag med skydækket — du har brug for at køle huset og tænde lyset samtidig) og andre gange, hvor det er meget mindre (en dejlig forårsåften, når alle er gået i seng). Den største mængde strøm, huset har brug for, når det fungerer ved fuld elektrisk kapacitet, kaldes spidsbehovsbelastning.

**SPØRGSMAål**

Hvor mange megawatt-timer bruger et gennemsnitligt hjem i Danmark hvert år? Hvad med i USA?
ELEKTRICITETSDISTRIBUTION

Distribution drøftes ofte, når det handler om vedvarende energi. Det er fordi mange af de bedste geografiske områder til vedvarende energiproduktion befinder sig langt væk fra storbycentre. Et meget omtalt eksempel er, at Sahara-ørkenen i Nordafrika er det ideelle sted for store solinstallationer, der potentielt kunne dække strømforbruget til hele Europa og Afrika.

Konventionelle højspændingstransmissioner er begrænset af spændingsfald langs ledningerne (ved hver kontakt, leder og selv langs selve ledningen er der en vis grad af modstand). Tab har en tendens til at være omkring 7% pr. 1000 km for højspændingsledninger med vekselstrøm over lange afstande. Jo højere spændingen er, jo mindre modstandstab er der. Denne fordel ved højspænding opretholdes i op til 2000 kV (hvor andre tab begynder at have effekt fra koronaudladning). Højspændingsledninger er typisk mellem 115 kV til 1200 kV, afhængig af ledningens længde (spændingen, der når vores hjem er på mellem 120 V til 240 V).

Den anvendelige grænse for højspændingstransmissioner med vekselstrøm er 7000 km, men energitabet over en sådan afstand er næsten 50 %. Højspænding med jævnstrøm er en anden mulighed, som kun resulterer i tab på 3% pr. 1000 km. Jævnstrøm er vanskeligere at regulere i spændingen, men til høj kapacitet over lange afstande er det en god idé.

TAG ET ØJEBLIK og tænk over de fordele, risici eller utilsigtede følger, der kan opstå ved at koncentrere strømproduktion på fjerne steder som i Sahara-ørkenen.

VEKSELSTRØM OG JÆVNSTRØM

Historien om forholdet mellem vekselstrøm (AC) og jævnstrøm (DC) begynder i slutningen af det 19. århundrede med Thomas Edison, som var stærk fortaler for jævnstrømsystemet, da han på det tidspunkt ejede mange af patenterne til jævnstrømsudstyr, der dominerede den elektriske infrastruktur.

Jævnstrømsystemet virkede for det meste vældigt godt med undtagelse af, at elektricitetsværket skulle befinde sig ca. 1,6 km fra anvendelsesdestinationen (belastningen). Dette skyldes, at teknologien på det tidspunkt ikke gjorde spændingsspring muligt (jævnstrømstransformere var ikke særligt effektive dengang), så strømmen skulle producieres og transmitteres ved en lidt højere spænding end den tilsigtede belastnings. Hvis du ville forsyne en 100 V-pære med strøm, producerede du og transmitterede strømmen ved 110 V blot for at tage højde for transmissionstab. Og hvis du havde flere stykker udstyr, der skulle tilføres strøm af forskellige spændinger, skulle du køre helt separate ledninger til kilden. Selvom distribuert produktion var mere demokratisk (muliggjorde energikooperativer og begrænsede monopolisering af strømproduktionsinfrastruktur), var det også ret upraktisk.

Omkring midten af 1880’erne efter Roms elektrificering med vekselstrøm, var det blevet klart for mange, herunder George Westinghouse, at vekselstrømsteknologi var mere effektivt til transmission af højspænding over lange afstande og med mindre tab. Siden da har vekselstrøm været den universelle standard, men dette kan ændre sig i de kommende årtier.

Interessant nok kører digital forbrugerelektronik i dag (transistorer og LED’er) hovedsagneligt på jævnstrøm og disse enheder udgør ca. 1/5 af elektricitetsforbruget i i-landene. Gregory Reed, direktør for Power & Energy Initiative på University of Pittsburgh, er en af dem, der er fortaler for den produktivitet, der kan opnås ved at skifte til en infrastruktur med jævnstrøm. Med en stigning i solkraftproduktion (som er jævnstrøm), den eksponentielle vækst af computerkraft og datacentre og den forestående elektriske bil-revolution, giver det mening at fjerne vekselstrøms transmissionskomponenten helt fra distributionssystemerne hvor vekselstrømsenhederne hører til fålallet af slutbrugerrudstyr (hver gang elektricitet konverteres fra jævnstrøm til vekselstrøm og tilbage igen, sker der et effekttab). Med en ældrende infrastruktur med vekselstrømsudstyr, er timingen nu perfekt til en revurdering af fordelene ved jævnstrøm. Hvis blot Edison kunne være vidne til dette!
AEROELASTISK FLUTTER
En selvfølende, regulær vibration, der forekommer, når vind passerer forbi et objekt og stimulerer objektets naturlige frekvens, som forårsager en positiv tilbagekoblingssløjfe. Denne ofte destruktive virkning undgås i flyvemaskinevinger og brokonstruktioner, men denne virkning kan udyttes med til vindkraftproduktion sammen med piezoelektricitet.

AFFALD TIL ENERGI (WtE)
Anvendelsen af ikke-genbrugeligt affald til forbrænding, der producerer elektricitet eller i nogle få tilfælde til omdannelse til methan eller lignende brændsel.

Der er visse nye WtE-teknologier, der ikke kræver forbrænding:
• Gasificering (producerer brint, syntetiske brændsler)
• Thermisk depolymerisation (producerer syntetisk råolie)
• Pyrolyse (producerer brændbar tjære, bioolie og biokul)
• Plasmabuegasificering, PGP (producerer syngas) Ikke-termiske teknologier:
• Anaerob forøjelse (biogas med højt methanindhold)
• Gæringsproduktion (ethanol, mælkesyre, brint)
• Mekanisk, biologisk behandling (MBT)

Kalkstensvaskere kan reducere emissionen af skadelige kemikalier fra WtE-forbrænding, og selvom der frigives CO₂ er effekten af dette mindre end de mere toksiske drivhusgasser der produceres på lossepladser i deres afgasning af methan, selvom meget af den methan genindvindes.

ALGEBIOBRÆNDESTOF
Alger kan dyrkes og høstes (algekultur) som råstof til produktion af alternativer til fossile brændsler. Naturligt forekommne olier i algerne (lipider) kan anvendes direkte (i sti med ren vegetabilsk olie) eller de kan raffineres, så de brænder renere. Forskellige produktionsmetoder kan resultere i biodiesel, biobutanol, biobenzin, methan, ethanol og endog flybrændstof. Optagelsen af CO₂ af algerne under kultiveringen forskyder den CO₂ der emitteres under forbrænding af algeproduceret brændstof. Alger kan producere op til 300 gange mere olie pr. hektar end konventionelle afgrøder såsom ægte purgernød, palme, rapsfrø eller sojabønner og kan kultiveres på steder, hvor disse typer afgrøder ikke er levedygtige.

AMORF SILICIUM (A-SI)
Det fungerende halvledermateriale inden for en type fotovoltaisk system (tyndfilm), der er mindre dyr og mere alsidig i sin anvendelse end krystallinske siliciumtyper. Omdannelsesvirkningsgraden er generelt ringere end krystallinsk silicium PV. Se ”monokrystallinsk silicium” for yderligere information.

BÆREPLAN (AEROFOIL)
Formen af en vingesektion, der er designet til at give løft og trække kræfter ved at skabe positivt og negativt trykluft på formens modsatte sider.

BIOGAS OG BIOMASSE

BRÆNDESELCELLE
Alle mekaniske systemer, konverterer energien, som er lagret i en brændselskilde (f.eks. brint, methanol), til elektricitet gennem en oxideringsproces. Brændselscelle kræver supplering af brændselskilden (reaktanten) for at kunne opholde den elektriske effekt. Brændselscelleteknologi har potentielle til at kunne erstatte den indvendige forbrændingsmotor til omdannelse af brændsel til energi til anvendelse i transport og maskineri.

DATAOVERVÅGNING
Realitetsstatistik over hvor meget elektricitet, der produceres. Overvågningen kan enten foregå på stedet eller via fjernadgang og vises i et grafisk interface, der er nem at forstå, og som ofte simulerer analoge drejeskiver og målere.

DRAGEGLIDER
En lille type glidende flyvemaskine, der normalt opsendes til fods.

DRAGEVINDKRAFT ELLER VINDDRAGE
Se vindkraft høj over havoverfladen (HAWP).

EFFEKTIVITET (ENERGIOMSÆTNINGSEFFEKTIVITET TIL ELEKTRICITET)

ELEKTRODE
Den elektriske leder, der har kontakt med en halvleder eller andet ikke-metallisk materiale. Elektroder kan mærkes som enten en anode eller en katode, afhængig af hvilken retning, den elektriske ladning strømmer.

ELEKTROSTATISK
Har at gøre med opbygningen eller afladningen af statisk elektricitet sædvanligvis gennem triboelektrisk effekt, hvor et materiale videregiver elektroner til et andet materiale gennem fysisk kontakt.

FARVEFØLSOMME SOLCELLER (DSSC)
Teknikker til dannelse af farvefølsomme solceller (DSSC) er simple og materialerne er meget billige, men omdannelsesvirkningsgraden er også mindre end faststofshalvleder-teknologierne omdannelsesvirkningsgrad (DSSC er den mest effektive af tredje-generations tyndfilm). Denne teknik blev opfundet i 1991 af Michael Grätzel og Brian O'Regan ved EPFL. DSSC-solcellen kaldes også Grätzel-cellen. De er bla. halvtransparente, fleksible og meget hårdføre. De fungerer også bedre end andre PV-teknologier under lave lysforhold og indirekte lys. Da de er så billige at producere har de en af de laveste priser/ydelsesforhold, og er derfor potentielt konkurrencedygtige med konventionel energi hvad angår gennemsnitlige omkostninger (kr. pr. kWh over installationens levetid) på trods af deres lavere omdannelsesvirkningsgrad.
**FORSYNINGSNIVEAU**
Signifikant strømproduktion, der kan distribuere energi til forsyningsnettet (i modsætning til strømproduktion “på stedet” til lokal brug).

**FOTOVOLTAIK (PV)**
Den fotovoltaiske effekt, der først blev opdaget af A.E. Becquerel i 1839, er et materiales evne til at producere jævnstrømselektricitet, når det udsættes for solstråling. Det henviser til den fotoelektriske effekt, som er frastødning af en elektron fra et materielt stof (sædvanligvis et mere højtledende metal sammenlignet med et halvleddermateriale) vha. elektromagnetisk stråling på det stof. I den fotovoltaiske effekt forbliver elektronerne i materialet (pga. semileddermaterialets beskaffenhed) og danner positive og negative bånd, som kan udnyttes vha. et elektrisk kredsløb.

**FOTOVOLTAISK OPTISKE FIBER**
Anvendelsen af optisk fiber til at styre sloyset over på fotovoltaiske celler, typisk farvefølsomme solceller (DSSC), som kan anvendes på fleksible overflader.

**FRESNELLINESE**
En forstørrende linse, der tager den sektionsdelte geometri fra en simpel konveks linse og flader den ud ved at skære den i koncentriske cirkler og forskyde de skivesårne segmentprofiler, så de danner en udfiødt, korrugeret overflade. Linsens optiske effekt er meget i stil med den originale konvekses linsens. Fresnellinser anvendes i mange koncentrerede fotovoltaiske systemer til at fokusere solens energi på specielt konstruerede fotovoltaiske celler.

**HALVTRANSPARENT FOTOVOLTAIK**
Solceller, der er indkapslet i et transparent materiale på en sådan måde, at lyset delvist kan passere igennem. Mønstret på det fotovoltaiske materiale kan være lille eller stort, mønstret eller uregelmæssigt.

**HELIOTROPISK (HELIOSTATISK)**
Evnen til at følge solens placering på himlen og vedligeholde et objekts konstante forhold til den gennem døgn- og årstidsforskydning. Inden for solenergi teknologi kan heliostatiske mekanismer opretholde en solcelles vinkelret på sloyset for ideel absorption og omdannelse eller spejle kan opretholde et incidensvinkelforhold til solen, så sloyset konstant reflekteres til en central opsamler.

**HYDRAULISK VINDMØLLE**
En roterende motor, der drives via kraften fra passerende vand.

**HYGROELEKTRICITET**

**HYDROELEKTRISK LAGRING**
Overskydende elektricitetskapacitet anvendes til at pumpe vand midlertidigt ind i et opstrømss reservoir. Vandet kan dernæst senere frigives, når der er behov for elektricitet og vha. tyngdekraften køres hydrauliske turbinedelelektriske generatorer i stil hermed til konventionelle hydroelektriske dæmninger, som er afhængig af naturlige nedbørscykluser til at kunne tilvejebringe vandkilden.

**JÆVNSTRØM (DC)**
Et elektrisk system hvor gennemstrømningen af den elektriske ladning er konstant (i modsætning til vekselstrøm, hvor gennemstrømningen regelmæssigt skifter retning). Se “Vekselstrøm” for yderligere oplysninger.
KAPACITETSFAKTOR
En multiplikator, der anvendes til at beregne gennemsnitseffekten af en energiproducerende enhed over en vis tidsperiode. Denne faktor tager højde for forhold, der ikke er ideelle og som bidrager til, at enheden fungerer under den nominelle kapacitet i løbet af visse perioder. Se “nominel kapacitet” for yderligere information.

KILOWATT (KW)
Lig med 1.000 watt. Se “watt.”

KILOWATT-TIME (kWh)
Lig med 1.000 watt-timer. Se “watt-time.”

KOBBERINDIUMGALLIUMSELENID (CIGS)
Et halvledermaterialealternativ til silicium, der anvendes i tyndfilms-fotovoltaik.

KOMPAKT VINDACCELERATIONSMØLLE (CWAT)

KONCENTRERET SOLKRAFT
Beskriver en række systemer, der anvender spejle eller linser til at koncentrere solens kraft for at kunne producere varmeenergi, der dernæst kan konverteres til elektricitet.

KONVEKTIONSSLØJFE
I væske- eller gasdynamik er det tendensen af højere tryk og lavere tryk til udligning, forårsager at varme vandrer mod kulde og således skaber en gennemstrømning af gas eller væske. I lukkede systemer med varmeefekt i et område skabes der en kontinuerlig sløjfe, idet varme materialer strømmer til kølige områder.

KULDIOXID (CO₂)
Kuldioxid, som er en naturligt forekommende kemisk forbindelse, der er væsentlig for livet på jorden, fungerer også som en drivhusgas (GHG) i jordens atmosfære. Menneskeskabte emissioner af CO₂ gennem forbrænding af fossile brændsler har siden industrialiseringen skabt en stigning på 35 % i dele pr. million (ppm) koncentration af gassen i jordens atmosfære. Siden 1960 er koncentrationen gået op fra 320 ppm til 390 ppm og yderligere stigninger truer med hurtige skift opad i globale temperaturer og havniveauer. For at kunne undgå en temperaturstigning på over 2°C skal mellem 2/3 og 4/5 af de kendte reserver af fossile brændsler forblive ubrugte indtil dokumenterede CCS-metoder (carbon capture and storage) kan muliggøre en sikker forbrænding af disse (ingen CCS-metode har endnu vist sig at være egnet til langtidsopbevaring af CO₂). Øgede atmosfæriske koncentrationer af CO₂ har også en sekundær effekt på havenes kemiske komposition, da kuldioxid på overladden opløses og danner andre kulforbindelser, der fører til forsuring.

LED
Lysemitterende diode, en halvleder-lysikilde. OLED er en LED, der er fremstillet af organiske forbindelser.

LINEÆR GENERATOR
En lineær motor anvendt som en strømgenerator til vekselstrøm. Lineære motorer er ikke afhængig af drejningsmoment og rotation, men snarere af enkel, lineær bevægelse.

MEGAWATT (MW)
Lig med 1.000.000 watt-timer. Se “watt-time.”

MEGAWATT-TIME (MWh)
Lig med 1.000.000 watt-timer. Se “watt-time.”
MIKROVINDMØLLE
En lille vindmølle med en spidskapacitet på mindre end 3000 watt.

MONOKRYSTALLINSK SILICIUM
Silicium (Si) er et halvledermaterial, der viser den fotovoltaiske effekt. Det var det første materiale, der blev anvendt i solceller og er stadig det mest overlegne. Det kan anvendes i enten krystallinsk (wafer) form eller i en ikke-krystallinsk (amorf) form. Der er to typer krystallinsk silicium: monokrystallinsk og polykrystallinsk (også kaldet multikrystallinsk). Monokrystallinsk silicium er meget dyrt at fremstille (da det kræver, at der skæres skiver af cylindriske støbeblokke af siliciumkrystaller, der er dyrket med Czochralski-metoden), men det er den mest effektive teknologi med krystallinsk silicium. Omdannelsesvirkningsgraden er omkring 23 %.

NOMINEL KAPACITET
Standardmæssig og konstant kraft, som en energiproducerende enhed kan producere i et ideelt miljø.

OMNIDIREKTIONEL FOTOVOLTAIK
I stand til at omdanne sollys til elektricitet ved alle vinker i forhold til solen. De fleste PV-teknologier kræver enten eller arbejder bedst ved en vinkel, der er vinkelret i forhold til solens placering på himlen.

ORGANISK FOTOVOLTAIK

PARABOLSK TRUG
En type koncentreret solkraft, der anvender en lang overflade med spejle med en tværsnitsform som en parabel. Sollys, der rammer spejloverfladen (på en vinkel, der er parallel med parabelens midterakse), rettes mod parabelens fokuspunkt og tilvejebringer energi til en varmeoverførselsvæske, der løber kontinuerligt langs dens længde. Varmeoverførselsvæsken kan anvendes til at producere den damp, der er nødvendig for vindmøllegeneratorer.

PARA-DRAGE
En serie drager på en snor, der er designet til at flyve i tandem eller en af dragerne i serien.

PARAFOIL
Et ikke-stift bæreplan, der typisk er fremstillet af ripstop-nylon med en aerodynamisk cellestruktur, der fyldes af vinden. Parafoilen tvinges ind i et vingetværsnit gennem fyldning med “ram air.”

PIEZOELEKTRISK GENERATOR
En enhed, der producerer elektrisk strøm fra trykkraft. Almindelig anvendelse af en piezoelektrisk enhed er som tændingskilde til gasovne og griller med “trykknapsstartere.”

PNEUMATISK KONDENSATOR
En enhed, der anvendes til trykluft eller anden inert gas.

PNEUMATISK MEMBRAN
En membran, der kan fyldes. PTFE-belagt glasfiberstof og ETFE-folie kan anvendes til at danne permanente membranstrukturer.
RÅVARE
I kraftproduktion henviser dette ord til energikilden som den eksisterer i ikke-elektrisk form. Dette kan være kemisk energi (petroleum og biobrændsel), strålings- eller termisk energi (sol) eller tyngdekraft (hydro) eller mekanisk (vind og bølge).

RECIPROKERENDE
Har at gøre med en gentagen fremad- og tilbagegående eller opad- og nedadgående lineær bevægelse.

SMART GLAS
Glas, der er i stand til at ændre transparens, når det påføres spænding.

SOLOPDRIFT (SOLSKORSTEN)

SOLSTOF
Fleksibelt fotovoltaisk materiale, der er integreret i lærred.

SOLVARMÉ
Solstråling, der anvendes til at varme et medium, såsom vand eller luft.

SPIDSKAPACITET
Det højeste designkapacitet en energiproducerende enhed kan håndtere under ideelle forhold og nyligt installerede komponenter.

STIRLING VARMEMOTOR
Enhed, der omdanner varme til mekanisk energi med høj effektivitet. Denne mekaniske energi kan dernæst anvendes til at drive en elektrisk generator.

TENSEGRITET
Individuelle strukturelementer (sædvanligvis metaltremmer), der arbejder i kompression suspenderes væk fra hinanden via et kontinuerligt spændingsnet (består normalt af metalkabler). Betegnelsen blev opfundet af Buckminster Fuller som en sammentrækning af “tensional” og “integritet.” Det strukturelle system blevet anvendt i mange kunstværker i det offentlige rum, herunder værket af Kenneth Snelson.

TREMOAKKUSISK MOTOR
En enhed, der anvender varmedifferentialer til at producere lydbølger eller omvendt, anvender lydbølgenergi til at overføre varme.

TREDJEGENERATIONS-FOTOVOLTAIK
Betegnelse, der anvendes om teknologiske innovationer, der har muliggjort solcellers omdannelsesvirkningsgrader til at stige kraftigt via tandem- eller multiovergangsstrukturer, der har varierende båndgab (materialets fysiske egenskab, der vedrører gennemstrømningen af elektroner gennem det eller fra det under forhold med excitation såsom den fra solstråling). I solceller med enkelt overgang tabes der energi, når fotoexcitationen overstiger grænserne for den særlige halvleders båndgab.

TYNDFILM
Som anvendt i fotovoltaik, alle ikke-krystallinske solcelleteknologier, der kan påføres i meget tynde lag, og således reducere materialemekostningerne.
Varmeafledersløjfe fra Vandkilde

En geotermisk eller jordkilde varmepumpe, der har en afkølende kapacitet. Vand passerer via den spiralformede slange gennem jorden (som opretholder en konstant temperatur mellem 10°C og 16°C afhængig af højden over havets overflade) og anvendes dernæst til afkøling af bygningen indvendigt via en varmeveksler.

Vekselstrøm (AC)

Et elektrisk system hvor gennemstrømningen af den elektriske ladning regelmæssigt skifter retning (i modsætning til jævnstrøm, hvor gennemstrømningen er konstant). Vekselstrøm blev taget i brug tidligt som standarden for elektrisk forsyningsdistribution pga. af det faktum, at transmissionstabene over store afstande var mindre end med jævnstrøm (DC). Moderne teknologier har gjort højstrømandsmissioner med jævnstrøm (HVDC) den foretrukne løsning for visse distributionsapplikationer til store afstande (mindre transmissionstab), men dette kræver, at strømmen ændres fra vekselstrøm og tilbage til vekselstrøm i begge ender med dyrt konverteringsudstyr.

Venturi-effekt

Når en fluid, såsom luft, er i bevægelse og indsnævres i dens bane, som af en sluse, for eksempel, vil fluidens hastighed stige og dens statisk tryk vil blive reduceret. Virkningen kan mærkes i urbane områder, når man står mellem to høje bygninger, som sammen virker som en sluse. Dette princip er inkorporeret i designet i kompakte accelerationsvindmøller (CWAT).

Vindkraft højt over havoverfladen (HAWP)

Vindens kraft højt over havoverfladen er meget stærkere og mere konstant i forhold til nærmere mod jorden. Der er imidlertid og naturligvis udfordringer i at få adgang til at uddybe denne udmærkede energikilde til elektriske formål. HAWP har potentielle til at være en billig og konstant energikilde. Der er en lang række teknologier, der i øjeblikket er i gang med at blive udviklet. Mange design er afledninger af drage- og sejlteknologi. Andre typer HAWP-enheder (luftbårne vindmøller eller AWT) anvender lettere-end-luft-balloner (aerostater), der roterer mellem to kabler eller små svæveflyver-agtige maskiner, der er designet til at flyve i en konstant cirkel eller otte-figur. I disse teknologier udføres omdannelsen af energi til elektricitet i himlen.

Vindmøllerotor

Den bevægelige del af en vindmøllemotor, som består af en tromme eller et skaft med blade fastgjort til den/det.

Vindrose

En grafisk repræsentation af vinden et hvilket som helst sted målt over en længere periode. Vindrosediagrammet viser hyppigheden af vindhastighed og den kardinalre retning, vinden blæser fra.

Vindmøller med lodret akse

Alle vindmøller, hvis roterende akse er lodret (vinkeltret med jorden). Typer af vindmøller med lodret akse omfatter Savonius, Darrieus (piskeris), og Giromills.

Vindmølle

En roterende motor, der drives via kraften fra passerende vind, der kan omdanne rotationskraften til elektrisk strøm.

Watt (W)

Måleenhed for elektrisk strøm, der svarer til 1/746 hestekræfter. $W = \text{Volt} \times \text{Ampere}$

Watt-time

En elektrisk energienhed, der svarer til en watt strøm, der anvendes eller produceres i løbet af en time.
ART+ ENERGY

Flash Cards

LAND ART GENERATOR INITIATIVE

THE CARDS

The rest of this PDF document contains the actual Flash Cards with energy-related problems to solve. You can work on just a couple or go through all of them. You can work in any order that you like (they’re not sequential).

Each flash card highlights one of the proposals to the Land Art Generator Initiative design competitions.

First take a look at the page with the large image of the artwork. There you will find some important facts about the technology that it incorporates along with two questions to solve.

Look at the next page to see the answers worked out and to learn more about the artist’s intentions behind the creation of their public art vision.
QUESTION 1 / SPØRGSÆL 1
With 80,000 square meters of photovoltaic surface, and assuming a capacity factor of 8%, what would be the annual electrical generation output of Light Sanctuary?

MED 80,000 kvm fotovoltaisk overflade og en formodet kapacitetsfaktor på 8 %, hvad ville den årlige elektricitetsproduktionskapacitet være for Light Sanctuary?

QUESTION 2 / SPØRGSÆL 2
Based on the annual electrical generation capacity that you calculated in Question #1, how many inefficient homes (10 MWh per year) could Light Sanctuary power?

Baseret på den årlige elektriske produktionskapacitet, som du udregnede i Spørgsmål nr. 1, hvor mange effektive hjem (6 MWh pr. år) kan Light Sanctuary så forsyne med elektricitet?

NAMEPLATE CAPACITY / SPIDSKAPACITET
82 watts per square meter (8.2% efficiency)
82 watt pr. kvm (8,2 % effektivitet)

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER
organic photovoltaic thin film
organisk fotovoltaisk tyndfilm
Light Sanctuary brings meaning to the idea of the mirage as a scintillating fluid structure. It is a sea of ribbons floating above the land and reaching out toward the water’s edge.

Forty kilometers of photovoltaic material is raised like a continuous flag a minimum of six meters above grade. The ribbons, each 10 m in height, are poised on a network of strong but slender masts, recalling the structure of nomadic fabric architecture. The surfaces are made of third generation photovoltaics, laminated in one continuous piece. The material possesses an inherent beauty: the surprising amber and pomegranate tones of its translucent surface evoke the resins, silica, and clays that are part of the desert’s natural botanical and geological resources.

Unlike older silicon-based panels, these translucent membranes can absorb light across 140° relative to their surface. This enables them to function when installed vertically, which minimizes the accumulation of dust and sand. An elliptical viewing platform may be reached by walking up a curving path that guides the viewer up through a shaded forest of supports, through a sea of amber, and to a promenade just above the ribbons.

**Light Sanctuary** giver mening til ideen om luftspejlingen som en funklende, flydende struktur. Det er et hav af bånd, der svæver over landet og rækker ud mod vandkanten.

40 km fotovoltaisk materiale er hejst som et kontinuerligt flag mindst seks meter over jordens overflade. Båndene, der hver måler 10 m i højden, er hævet på et netværk af stærke, men tynde master, der strukturelt minder om nomadearkitektur. Overfladerne er kontinuerlige lamineringer af tredjegenerations fotovoltaik, som har en naturlig skønhed: de overraskende røgylde og granatæblefarvede toner af deres gennemslagsige overflader vækker harpiksen, siliciummet og lertyperne til live, der er del af ørkens naturlige botaniske og geologiske ressourcer.

I modsætning til ældre siliciumbaserede paneler, kan disse gennemslagsige membraner absorberes lys over 140° i forhold til deres overflade. Dette gør det muligt for dem at fungere, når de installeres lodret, hvilket minimerer akkumuleringen af støv og sand. En elliptisk udsigtsplatform nås via en rampe og en bøjet sti, der guider gæsten op gennem en skyggefuld skov af støtter, op gennem et hav af røg, og på en spadseretur lige over båndene.
**QUESTION 1 / SPØRGSMÅL 1**
Assume the installation contains 200 wind turbines with a capacity factor of 25% and 1000 square meters of photovoltaic surface with a capacity factor of 14%. What would be the annual electrical generation capacity of WindNest?

Antag, at installationen indeholder 200 vindmøller med en kapacitetsfaktor på 25 % og 1000 kvm fotovoltaisk overlade med en kapacitetsfaktor på 14 %. Hvad ville den årlige elektricitetsproduktionskapacitet på WindNest være på?

**QUESTION 2 / SPØRGSMÅL 2**
Based on the annual electrical generation capacity that you calculated in Question #1, how many inefficient homes (10 MWh per year) could WindNest power?

Baseret på den årlige elektriske produktionskapacitet, som du udregnede i Spørgsmål nr. 1, hvor mange effektive hjem (6 MWh pr. år) kan WindNest så forsyne med elektricitet?
Simultaneously embedded in the landscape and floating in the air, WindNest is a macro scale land art installation that harnesses wind and sun energy for performative effects. The multi-stranded system grows from the subtle dunescape at the site, allowing for raised viewing platforms as well as erosion protection and habitat corridors.

Hovering above and on the verge of take-off, a network of windsock turbines dynamically registers wind movement across the field, producing both energy and atmospheric effects. WindNest relies on two means of energy collection. Each of the windsocks is fitted with an energy collection turbine (compact acceleration wind turbine) and one third of the windsocks are covered with solar fabric. The proposal utilizes low-impact, lightweight materials chosen in consideration of the full life-cycle of the project from material production to construction, maintenance and even after its role as a public art installation.

**WindNest**, som både er indlejret i landskabet og svæver i luften, er en land art installation i makroskala, som udnytter vindens og solens energi. Systemet med de mange elementer vokser ud af det diskrete klitlandskab på stedet og indbyder til hævede udsigtsplatforme samt erodersionsbeskyttelse og habitatkorridorer.

Svævende over og på nippet til at flyve af sted er et netværk af vindposevindmøller, der dynamisk registrerer vindens bevægelse på marken og både producerer energi og atmosfæriske effekter. WindNest anvender to energiindvindingsmetoder. Hver af vindposerne er udstyret med en energiindvindingsvindmølle (kom- pakt accelerationsvindmølle) og en tredjedel af vindposerne er betrækket med solenergistof. Forslaget benytter letvægtsmateri- aler med lavt CO₂ fodafryk, som er udvalgt under hensyntagen til projektets fulde livscyklus fra materialeproduktion til konstruk- tion, vedligeholdelse og selv efter dets rolle som en kunstinstalla- tion i det offentlige rum.
Assuming an average capacity factor of 0.227 for the 12 turbines that make up this installation, how much energy could Fresh Hills generate over the course of a year?

Based on the annual electrical generation capacity that you calculated in Question #1, how many inefficient homes (10 MWh per year) could Fresh Hills power?
As we approach Fresh Hills, the undulating mounds appear to be natural elements growing from the earth. The closer we get, however, it is clear that this structure, like the mounds below it, are not native to the recently capped Fresh Kills Landfill site.

Its form creates a harmonious relationship between earth and wind. Fresh Hills is a remedy for the typical turbine farm that so often isolates the landscape and discourages communities from engaging the space.

The apparatus is generated from the grafting of Freshkills Park’s windrose data onto the site, creating a seamless exchange between the site-specific data and the structure used to harness that information. The project is site-specific, but the concept provides global versatility.

The expansive surface area at the mouth of the mounds helps funnel wind towards the turbine and takes advantage of the fluid and dynamic nature of airflow. The structure guides the airflow creating a low-pressure system on the other side of the mounds resulting in a pastoral central plaza. As if standing at the eye of a storm, the central hub becomes a place to gather, reflect, play, and explore.


Apparatet er produceret ved at få tilføjet Freshkill Parks Windrose-data på stedet og derved skabe en problemfri overgang mellem stedets specifikke data og strukturen, der anvendes til at udnytte denne information. Projektet er stedsspecifikt, men konceptet indbyder til global alsidighed.

QUESTION 1 / SPØRGSMÅL 1
If each Heliofield unit has 7 m² of photovoltaic surface (capacity factor = 15%) and there are 8,252 units in the park, what is the annual output of the installation after deducting the 59.8 watt-hours per night that each unit uses for OLED illumination?

Hvis hver Heliofield-enhed har 7 m² fotovoltaisk overflade (kapacitetsfaktor = 15 %), og der er 8.252 enheder i parken, hvad er installationens årlige produktion så efter fradrag af de 59,8 watt-timer pr. nat, som hver enhed bruger til OLED-belysning?

QUESTION 2 / SPØRGSMÅL 2
Based on the annual electrical generation capacity that you calculated in Question #1, how many inefficient homes (10 MWh per year) could Heliofield power?

Baseret på den årlige elektriske produktionskapacitet, som du udregnet i Spørgsmål nr. 1, hvor mange ineffektive hjem (6 MWh pr. år) kan Heliofield så forsyne med elektricitet?

NAMEPLATE CAPACITY / SPIDSKAPACITET
200 watts per square meter (20% efficiency)
200 watt pr. kvm (20 % effektivitet)

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER
thin film solar
tyndfilm til solenergi
Heliofield is an array of photovoltaic units that rise from reclaimed areas of the former Fresh Kills landfill. The slender supporting legs of each unit are anchored separately with large, heavy feet that allow it to stand alone or deliver electricity throughout the system as part of an array of thousands. The flexibility and scalability of the system lends itself to the dynamic nature of the site.

In addition to meeting technological needs, the system also serves flora and fauna with a set of interchangeable habitat components that address the inherent ecological challenges of the site, such as shallow soil depth and lack of trees. Functional amenities are designed for small mammals, birds, insects, and plants and supplement the limited habitat of the former landfill at Freshkills Park.

As the sun dips below the horizon, Heliofield transitions from solar power plant to nighttime spectacle. Insects are attracted to the mysterious blue glow created by the OLED (organic light-emitting diode) lights that are integrated into every solar module. This nocturnal cycle is designed to cultivate an appreciation for local ecology and biodiversity while presenting a beautiful otherworldly display.

**ANSWER 1 / SVAR 1**

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nameplate capacity (spidskapacitet)</td>
<td>57764 m²</td>
</tr>
<tr>
<td>Capacity factor (kapacitetsfaktor)</td>
<td>0.15</td>
</tr>
<tr>
<td>Days per year (dage om året)</td>
<td>365</td>
</tr>
<tr>
<td>Hours per day (timer om dagen)</td>
<td>24</td>
</tr>
<tr>
<td>Wh → MWh (MWh)</td>
<td>10,000,000</td>
</tr>
<tr>
<td>57764 m² × 0.0000598 MWh per m² per day</td>
<td>15180 MWh</td>
</tr>
<tr>
<td>15180 MWh ÷ 10 MWh per year (inefficient home)</td>
<td>1500 homes</td>
</tr>
</tbody>
</table>

**ANSWER 2 / SVAR 2**

15000 MWh per year ÷ 6 MWh per year (dansk hjem) = 2500 hjem
QUESTION 1 / SPØRGSMÅL 1
With 3,330 linear meters of parabolic trough length installed and a capacity factor of 53%, what is the expected electrical output of Transpire in one year?

Med 3,330 lineære meter parabolske trug installeret, og en kapacitetsfaktor på 53 %, hvad er så Transpire’s forventede elektriske kapacitet på et år?

QUESTION 2 / SPØRGSMÅL 2
In dry coastal regions power generation can be easily equated with potable water supply, because desalination requires power. With a byproduct of 300,000 liters per day of potable water how many people can Transpire sustain (assume per capita consumption of 200,000 liters per year)?

I tørre kystområder kan energiproduktion let sidestilles med drikkevandsforsyningen, fordi afsaltning kræver strøm. Med et biprodukt på 300.000 liter om dagen af drikkevand, hvor mange mennesker kan Transpire så forsyne (lad os antage et forbrug på 200.000 liter pr. år pr. indbygger)?

NAMEPLATE CAPACITY / SPIDSKAPACITET
1940.4 W per meter of absorber tube
1940.4 W pr. meter absorberør

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER
solar thermal concentrated solar power (CSP) of the parabolic trough variety (single-axis tracking) with thermal energy storage
termisk koncentreret solkraft (CSP) af den parabolske trug-type (tracking med enkelt akse) med termisk energilagring
TRANSPIRE v. to emerge, to be made public

TRANSPIRATION n. a natural process similar to evaporation.

The expression of water from the aerial parts of plants as part of their energy cycle.

Transpire makes the invisible visible. On a long narrow site, one hundred iconic stainless-steel spires sway like barasti reeds and produce a soft shape-shifting cloud that clearly marks the site from a great distance. Elegant in its simplicity, the installation celebrates the alchemy of natural elements essential for human survival; sunlight and seawater transform into abundant electrical power, freshwater, and salt.

Against the backdrop of a flourishing acacia grove set in a moat of multi-hued crystallized salt, the spires and the floating cloud combine to create a meaningful and symbolic gateway to the city.

Transpire is a dynamic art venue. Imagery, films, and text created by invited artists or the public are projected onto the cloud bank at night. During the day, under certain atmospheric conditions, a rainbow will form, visible all the way from the city center.

ANSWER 1 / SVAR 1
3330 meters \times 1000 = 3330000 meters
\times 1940.4 W per meter \times 365 days per year \div 24 hours per day \div 1000000 Wh = 30000 MWh per year

ANSWER 2 / SVAR 2
300000 liters per day \times 365 days per year \div 20000 liters per person per year \div 547 people = 547 people
QUESTION 1 / SPØRGSMÅL 1
Each PV Dust host is a 50cm diameter sphere. With each Sphelar™ cell measuring only 2 mm, a host can fit 100,000 cells. With 350,000 hosts in the overall installation, and assuming a capacity factor of 25%, how much electrical power can PV Dust produce in a year?

Hver PV Dust vært er en sfære med en diameter på 50 cm. Hver Sphelar™ celle måler kun 2 mm, så en vært kan rumme 100,000 celler. Med 350,000 værter i den samlede installation, og under forudsætning af en kapacitetsfaktor på 25 %, hvor meget elektrisk strøm kan PV Dust så producere på et år?

QUESTION 2 / SPØRGSMÅL 2
Based on the annual electrical generation capacity that you calculated in Question #1, how many homes in the United States could PV Dust power?

Baseret på den årlige elektriske produktionsskæpse, som du udregnede i Spørsmål nr. 1, hvor mange supereffektive lejligheder (3,5 MWh pr. år) kan PV Dust så forsyne med elektricitet?

NAMEPLATE CAPACITY / SPIDSKAPACITET
0.66 mW per cell (1000 mW = 1 W)
0.66 mW pr. celle (1000 mW = 1 W)

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER
thin film solar Sphelar™
tyndfilms Sphelar™ til solkraft
PV Dust is a site-specific land art installation producing clean energy with astonishing efficiency. PV Dust covers 175,000 m² of ground with a new breed of photovoltaic technology, aggregating into a cloud of energy-producing dust. The PV Dust cloud has a spectral presence, recalling the great desert sand storms of the Arabian Desert. Below the cloud, a network of sand-colored gravel paths striates the territory in a pattern of traditional Islamic lattices.

PV Dust is designed on a cubic 25 meter modular grid. There are 279 of these modules featuring innovative, omni-directional PV technology. PV Dust fits on just 174,375 m² of land. This is about 57% of the catchment of flat thin film photovoltaic panels with the same electrical output.

Sphelar™ Cells can be connected in parallel or in series. This enables diverse spherical products to be created, such as dome-shaped solar cells and flexible solar cells aligned on soft film substrates. PV Dust assumes Sphelar™ Cells are grafted on a light plastic sphere of 500 mm diameter, called a host. Collectively, the hosts make the PV Dust cloud formations.

**PV Dust** er en stedsspecifik land art-installation, der producerer ren energi med forbavsende effektivitet. **PV Dust** dækker 175.000 m² af jorden med en ny type fotovoltaisk teknologi, der samler sig til en sky af energiproducerende støv. **PV Dust**-skyen har et lidt uhyggeligt udseende og minder om de store ørkensandstormer i den arabiske ørken. Under skyen krydser et netværk af sandfarvede grusstier territoriet i et mønster, der imiterer traditionelle, islamiske gitterstrukturer.

**PV Dust** er designet på et kubisk 25 meter modul. Der er 279 af disse moduler, der anvender innovativ, omni-direktionel PV-teknologi. **PV Dust** kan være på kun 174.375 m² land. Dette er omkring 57 % af reservoiret for de flade tyndfilms fotovoltaiske paneler med samme elektriske kapacitet.

Sphelar™ celler kan forbindes parallelt eller i serier. Dette gør det muligt at skabe alsidige, sfæriske produkter, såsom kuppeformede solceller og fleksible solceller, der er justeret ind på bløde filmsubstrater. **PV Dust** formoder, at Sphelar™ cellerne anbringes på en let plastiksfære på 500 mm i diameter, kaldet en vært. Samlet udgør værterne **PV Dust**-skydannelserne.

**ANSWER 1**
100000 cells per host celler pr. vært × 0.68 mW per cell 0,68 pr. celle nameplate capacity spidskapacitet ÷ 1000 mW per W værter × 350000 hosts værter × 0.25 capacity factor 0,25 kapacitetsfaktor × 365 days per year dage om året × 24 hours per day timer om dagen ÷ 1000000 Wh -> MWh 50589 MWh per year om året

**ANSWER 2**
50589 MWh per year ÷ 10 MWh per year (inefficient home) = 5059 homes
50589 MWh om året ÷ 3,5 MWh om året (supereffektiv lejlighed) = 14.454 lejligheder
QUESTION 1 / SPØRGSMÅL 1
Each algae tree has 2,180.27 linear meters of 10 cm diameter tubing which equates to 684.93 m² of surface exposed to the sun. Using a 20% capacity factor, how many liters of biobutanol can a Shifting Algae Forest of 2,500 trees generate every year?

Hvert algetræ har 2.180,27 løbende meter med rør på 10 cm i diameter, der svarer til 684,93 m² overflade, der eksponeres for sol. Med en 20 % kapacitetsfaktor, hvor mange liter biobutanol kan Shifting Algae Forest på 2.500 træer så generere hvert år?

QUESTION 2 / SPØRGSMÅL 2
Based on the number of liters of biobutanol that you calculated in Question #1, and assuming that this renewable liquid fuel is used in a fuel cell to create electricity at 7.5 kWh per liter, how many inefficient homes (10 MWh per year) could Shifting Algae Forest power? How many efficient homes (6 MWh per year)?

Baseret på antallet af liter biobutanol, som du beregnede i Spørgsmål nr. 1, og hvis vi antager, at dette vedvarende flydende brændstof anvendes i en brændstofcelle til at producere elektricitet ved 7,5 kWh pr. liter, hvor mange ineffektive hjem (10 MWh pr. år) kan Shifting Algae Forest så forsyne med energi? Hvor mange effektive hjem (6 MWh pr. år)?

NAMEPLATE CAPACITY / SPIDSKAPACITET
10 ml (0.01 liters) of fuel per hour for each square meter of algae exposed to the sun
10 ml (0.01 liter) brændstof pr. time for hver kvadratmeter alger, der eksponeres for sol

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER
Algae Biofuel (biobutanol)
Algebiobrændstof (biobutanol)
Shifting Algae Forest is an expression of future expectations for sustainable energy production and hybrid ecosystems. Shifting Algae Forest converts the harmful legacy of urban waste streams into a productive landscape. It is designed to be installed on a landfill site. Each tree in the forest takes up the landfill gas (LFG) through its central column. The liquid mixture in the algae tubes (the tree branches) is a combination of microalgae solution and the leachate (landfill liquid drainage) that is pumped up into the central column of the trees. Here, the LFG (landfill gas) meets the algae-rich water in the system’s photobioreactor. In order to allow this viscous mixture to flow under gravity, the photobioreactor tubes are configured in a sloping spiral form, thus activating the photosynthetic processes of the algae production. The CO₂ component of the LFG, which usually ranges from 40–50%, is quickly absorbed by the microalgae and enriched with oxygen, a byproduct of the microorganism’s photosynthesis. This oxygen-rich LFG is then put back into the existing gas collection pipeline network where it will feed a more refined methane into the city grid.

**Design Team**
Jessica Wolff, Abhishek Sharma, Pamela Richot, Ekachai Pattamasattayasonthi

**Shifting Algae Forest** er et udtryk for fremtidige forventninger til vedvarende energiproduktion og hybride økosystemer. **Shifting Algae Forest** omdanner de traditionelt skadelige byaffaldsstømme til et produktivt landskab. Det er designet til at blive installeret på en losseplads. Hvert træ i skoven optager lossepladsgas (LFG) gennem dets midtersøjle. Den flydende blanding i algerørene (træernes grene) er en kombination af mikroalgeopløsning og perkolat (sivevand fra lossepladsen), der pumpes op i træernes midtersøjler. Her møder LFG (lossepladsgassen) det algeholdige vand i systemets fotobioreaktor. For at gøre det muligt for denne tykt-flydende blanding at flyde under tyngdekraft er fotobioreaktorens rør konfigureret i en hældende spiralform, som således aktiverer algeproduktionens fotosyntetiske processer. LFG’ens CO₂, som normalt ligger mellem 40–50 %, absorberes hurtigt af mikroalgerne og beriges med ilt, som er et biprodukt af mikroorganismernes fotosyntese. Denne iltige LFG føres dernæst tilbage til det eksisterende gasopsamlingsledningsnet, hvor det vil levere en mere raffineret methan til byens forsyningsnet.

**Answer 1 / Svar 1**
- 684.93 m²
- × 0.01 liters per m²
- Nameplate capacity: Spidskapacitet
- × 0.20 capacity factor: 0,20 kapacitetsfaktor
- × 365 days per year: Dage om året
- × 24 hours per day: Timer om dagen
- × 2500 trees: Træer
= 29999934 liters: Liter

**Answer 2 / Svar 2**
- 29999934 liters per year: Liter pr. år
× 0.0075 MWh per liter
÷ 10 MWh per year (inefficient home: Ineffektivt hjem)
= 22900 homes: Hjem

- 29999934 liters per year: Liter pr. år
× 0.0075 MWh per liter
÷ 6 MWh per year (efficient home: Effektivt hjem)
= 37500 homes: Hjem
QUESTION 1 / SPØRGSMÅL 1
Each Blossomings unit has 6.68 m² of solar thin film surface area that functions with a capacity factor of 0.20. The VAWT operates at a capacity factor of only 0.10 (it is only nocturnal after all). Given this information, can you estimate how much electricity in kWh each Blossomings unit will generate in a year?

Hver enhed i Blossomings har 6,68 m² tyndfilmsoverflade, der fungerer med en kapacitetsfaktor på 0,20. VAWT opererer med en kapacitetsfaktor på kun 0,10 (den foregår nemlig kun om natten). Med disse oplysninger kan du så beregne, hvor meget elektricitet i kWh hver Blossomings-enhed genererer på et år?

QUESTION 2 / SPØRGSMÅL 2
Based on the annual electrical generation capacity that you calculated in Question #1, and assuming that each Blossomings has an embodied energy of 48,355.81 MJ (13.4322 MWh), how long is Blossomings’ energy recovery time in years?

Baseret på den årlige elektriske produktionskapacitet, som du beregnede i Spørgsmål nr. 1, og med en formodning om, at hver Blossomings repræsenterer en energi på 48.355,81 MJ (13,4322 MWh), hvor længe er Blossomings’ energigen-vindingstid så beregnet i år?
As a flower opens to receive the sun, Blossomings opens to harness photovoltaic energy during the day. In the evening, a flower closes to protect itself from the elements. Likewise, as sun energy disappears at night, Blossomings closes to function as a vertical wind turbine, converting wind energy into power output. It is a simple process, yet based on an intuition of nature.

Blossomings, with a shallow but wide footing, provides much needed shade in open areas during the day, while collecting solar energy for power the grid. Evening wind turbine activation protects wild bird life from being harmed, as they mostly migrate during the day.

The design strives to keep pragmatic functionality while remaining aesthetically stimulating through flux of movement and light to solicit contemplations of ecological and biomimetic systems.

Lige som en blomst, der åbner sig for at få sol, åbner Blossomings sig for at høste fotovoltaisk energi i løbet af dagen. Om aftenen lukker blomsterne sig for at beskytte sig mod vejr og vind. På samme måde lukker Blossomings sig, når solen forsvinder om natten og fungerer i stedet som en lodret vindmølle og konverterer vindenergi til elektrisk strøm. Det er en simpel proces baseret på naturens funktioner.

Blossomings, med en flad, men bred base, tilvejebringer den meget nødvendige skygge på åbne områder om dagen, mens den opsamler solenergi til forsyningsnettet. Vindmølleaktiviteten om natten beskytter vilde fugle mod at komme til skade, da de for det meste migrerer om dagen.

Designet har til hensigt at vise den pragmatiske funktionelitét, mens det samtidig er æstetisk stimulerende gennem bevægelse og lys for at frembringe fornemmelsen af økologiske og biomimetiske systemer.

**Answer 1 / Svar 1**

\[
\text{ANSWER 1 / SVAR 1}
\]

1. \((6.68 \text{ square meters} \times 0.150 \text{ kWp per m}^2 \times 0.20 \text{ capacity factor} \times 365 \text{ days per year} \times 24 \text{ hours per day}) + (1.250 \text{ kW} \times 0.10 \text{ capacity factor} \times 365 \text{ days per year} \times 24 \text{ hours per day})\)

\[
\begin{align*}
&= 2.8505 \text{ MWh per year/pr. år} \\
&= 2.8505 \text{ kWh} \rightarrow \text{ MWh}
\end{align*}
\]

**Answer 2 / Svar 2**

\[
\text{ANSWER 2 / SVAR 2}
\]

\[
\begin{align*}
&= 13.4322 \text{ MWh} \\
&= 2.8505 \text{ MWh per year/pr. år} \\
&= 4 \text{ years, 8 months, and 15 days} \\
&= 4 \text{ år, 8 måneder, og 15 dage}
\end{align*}
\]
QUESTION 1 / SPØRGSMÅL 1
Wind speed is greater and more constant at higher altitudes. This has the potential to bring the capacity factor of HAWT up significantly. But Wind Grazers uses solar energy to bring the turbines aloft, which means they are less productive at night on the ground. With a capacity factor of 40%, how much energy would all 200 turbines collectively generate in a year?

Vindhastigheden er større og mere konstant i større højder. Den kan bringe kapacitetsfaktoren for HAWT markant op. Men Wind Grazers anvender solenergi til at bringe vindmøllerne til tops, hvilket betyder, at de er mindre produktive om natten på jorden. Med en kapacitetsfaktor på 40 %, hvor meget energi ville alle 200 vindmøller så til sammen producere på et år?

QUESTION 2 / SPØRGSMÅL 2
If helium gas* was used to keep Wind Grazers aloft during the night, the capacity factor would be increased to 60%. How much energy would all 200 turbines generate in a year then? *It is important to note that helium is a non-renewable resource required to operate MRI equipment in hospitals and other important tools. Scientists are concerned that we are using helium at an unsustainable rate.

Hvis der blev anvendt heliumgas* til at holde Wind Grazers svævende om natten, ville kapacitetsfaktoren stige til 60 %. Hvor meget energi ville alle 200 vindmøller så producere på et år? *Det er vigtigt at bemærke, at helium er en ikke-vedvarende energikilde, den er påkrævet til at betjene MR-udstyr på hospitaler og andre vigtige værktøjer. Videnskabsmænd er bekymrede for, at vi anvender helium i et omfang, som ikke er holdbar.
Wind Grazers is comprised of a field of 200 turbines, designed to hover in the air above Freshkills Park—a 2,200 acre (890 ha) landfill on Staten Island (a borough of New York City). Laid out like rows of crops that call to mind the site’s agricultural past, 400-foot retractable tethers anchor an armada of aerial turbines. The equal lengths of tether create a virtual topography 400 feet in the air. These artificial hills and valleys are visible to the surrounding areas of Staten Island and New Jersey. The turbines are held aloft by a small, tube-shaped dirigible (airship), roughly 15 inch diameter by 20 feet long. Prototypes for this form of turbine have been engineered to operate at even higher altitudes (as much as 2000 feet) and can generate as much as 100 kW per turbine.

The dirigible is held aloft by utilizing its cell fabric as a solar collector. The black surface captures and super-heats the air necessary to keep the turbine elevated. After the air cools with the loss of solar radiation, the dirigible will slowly wilt to the ground where it will remain until the next day.

Each turbine’s current is relayed to a central switch at the park entrance, where teaching displays and meters quantify the operation to visitors. In addition, the turbines are equipped to relay wind speed, wind direction, and atmospheric pressure to complement the energy data.

The aerial topography marked by the floating wind turbines suggests the poetic potential of an alternate future.
QUESTION 1 / SPØRGSMÅL 1
The solar panels (3,613 m²) of Solar (ECO) System are arranged around spherical shapes at all angles to the sun. This reduces the capacity factor somewhat as compared to a fixed angle PV array. The location in the sun-rich United Arab Emirates and the high reflectivity (albedo) of the ground plane help the overall capacity factor to reach 16%. How much energy will Solar (ECO) System generate in one year?

QUESTION 2 / SPØRGSMÅL 2
If the same installation were to be located in a city with greater cloud cover and on a darker ground plane (lower albedo), the capacity factor would drop to 9%. How much energy would be generated in a year by Solar (ECO) System at this other site (size of the spheres remains the same)?
Solar (ECO) System celebrates the position of the planets on December 2, 1971—the day the United Arab Emirates was founded. The sun and each surrounding planet are created from photovoltaic materials of different shapes, colors, and textures. The astronomic sun radiating energy to the new photovoltaic sun will generate enough clean electricity to power a neighborhood.

Each of the orbs incorporates a different PV strategy to complement the artist’s conceptual imagining of the solar system.

PV Sun: golden and opaque mc-Si panels (10 meters radius)
Earth: semitransparent CIGS panels with the serigraphy of the continents (6.6 meters radius)
Crescent: semitransparent CIGS panels (3.6 meters radius)
Eclipse: black CIGS panels with black structure (6 meters radius)
Atmosphere: semitransparent CIGS modules (6.5 meters radius)
Craters: opaque and round mc-Si panels (5.8 meters radius)
Ring: opaque mc-Si modules (6.5 meters radius)
Gas Giant: semitransparent CIGS panels on photovoltaic solar shading system (6.2 meters radius)

The surface area of a sphere = $4\pi r^2$. Using this equation for each sphere separately and then adding them up results in the approximate total surface area of the spheres = 4,388 m². The area of voids in the PV Sun and Craters comprise about 775 m². Therefore, the actual surface area of the solar panels on Solar (ECO) System = 3,613 m².


Alle kloder inkorporerer en anderledes FV-strategi, som komplementerer kunstnerens konceptuelle forestilling af solsystemet.

FV-sol: gyldne og opakke mc-Si-paneler (10 meter radius)
Jord: semitransparente CIGS-paneler med kontinenternes serigrafi (6,6 meter radius)
Halvmåne: semitransparente CIGS-paneler (3,6 meter radius)
Ekliipse: sorte CIGS-paneler med sort struktur (6 meter radius)
Atmosfære: semitransparente CIGS-moduler (6,5 meter radius)
Kratere: opakke og runde mc-Si-paneler (5,8 meter radius)
Ring: opakke mc-Si-moduler (6,5 meter radius)
Gassgigant: semitransparente CIGS-paneler på fotovoltaisk solskyggesystem (6,2 meter radius)

Sfærens overfladeareal = $4\pi r^2$. Hvis vi bruger denne lighning til hver sfære separat og dernæst lægger dem sammen, resulterer det i sfærernes omtrentlige overfladeareal = 4.388 m². Tomrumsområderne i FV-sol og -kratere består af 775 m². Derfor er solpanelernes faktiske overfladeareal på Solar (ECO) System = 3.613 m².
QUESTION 1 / SPØRGSMÅL 1
Piezoelectric energy comes from ceramic discs whose physical properties produce small electrical charges when they are bent or when pressure is applied to them. To determine the capacity factor we should think about how much of the time the disc will be bent or under pressure. Assume that the discs generate peak energy 4 seconds of every minute on average (as wind blows the Super Cloud tubes back and forth). What is that capacity factor?

Piezoelektrisk kommer fra de keramiske diske, hvis fysiske egenskaber producerer små elektriske ladninger, når de bøjes eller når de påføres tryk. For at bestemme kapacitetsfaktoren, skal vi tænke på hvor meget af tiden, disken bliver bøjet eller kommer under tryk. Med udgangspunkt i de gennemsnitlige tider pr. minut i løbet af året, lad os så formode, at diskene producerer (spidskapacitet) energi 4 sekunder hvert minut i gennemsnit (når en vind blæser Super Cloud-rørene frem og tilbage). Hvad er kapacitetsfaktoren?

QUESTION 2 / SPØRGSMÅL 2
A stack of 49 discs (each with average power output of 6 watts) are at the base of each tube that gets bent by the wind. Using the capacity factor you arrived at in question #1 and assuming 14,500 tubes make up the entire Super Cloud artwork, estimate how much electricity could be generated each year.

En stabl på 49 diske (hver med en gennemsnitlig strømfekt på 6 watt) befinder sig i bunden af hvert rør, som bliver bøjt af vinden. Hvis vi anvender kapacitetsfaktoren, du fik i Spørgsmål nr. 1, og hvis vi formoder, at 14.500 fær udgør hele Super Cloud-kunstværket, hvor meget elektricitet kunne der så produceres hvert år?
Super Cloud mimics the movement of wind patterns. As each disc floats between ground and sea, vibrating in the wind, the installation acts as a dynamic element within the landscape of the city. Landscape, art, and energy act together in a cohesive system, delivering clean, renewable energy.

Super Cloud is made up of pliable carbon fiber pipes. A steel space truss structure (270 m x 60 m) lifts from the ground and anchors approximately 14,500 tubes (ranging from 2 m to 10 m). Half of these tubes are fastened to the top of the structure while the other half hang from the bottom. The varied sizes of circular, sectioned tubes capture the ever-changing direction of the wind.

The structural characteristics of the space truss allow the free placement of columns. The section of the horizontal structure is slimmer on the edges to create a disappearing effect and to enhance the illusion of floating.

The cloud embraces, enhances, and interacts with its environment, amplifying its changing states. Shadows, vibrations, and reflections create a unique aesthetic experience as weather conditions and site locations change.

Super Cloud imiterer vindmønstrenes bevægelser. Mens hvert rør svæver mellem jord og himmel og vibrerer i vinden, tjener de som et dynamisk element i byens landskab. Landskab, kunst og energi arbejder sammen i et sammenhængende system og leverer ren, vedvarende energi.

Super Cloud består af bøjelige kulfiberrør. En rumgitterstruktur af stål (270 m x 60 m) løfter sig fra jorden og forankrer ca. 14.500 rør (fra 2 m til 10 m). Halvdelen af disse rør er fæstnet til toppen af strukturen, mens den anden halvdel hænger nede fra bunden. De forskellige størrelser runde, opdelte rør indfanger vindens skiftende retning.

Rumgitrets strukturelle egenskaber muliggør fri placering af søjlerne. Strukturen er tyndere i kanterne for at skabe en forsvindende virkning og for at styrke den svævende illusion.

Skyen omfavner, fremhæver og interagerer med dens miljø og forstærker miljøets foranderlige tilstande. Skygger, vibrationer og refleksioner skaber en unik æstetisk oplevelse i takt med, at vejrforhold og stedet ændrer sig.
QUESTION 1 / SPØRGSÆL 1
There are 40,319 small wind turbines that create the form of *The Cloud*. Each turbine has a peak output capacity of 20 watts and operates at 30% capacity over the course of a year. How much energy in megawatt-hours can *The Cloud* generate each year?

Det er 40.319 små vindmøller, der skaber formen på *The Cloud*. Hver har en peak-effektkapacitet på 20 watt og fungerer ved 30 % kapacitet i løbet af et år. Hvor meget energi i megawatt-timer kan *The Cloud* producere hvert år?

QUESTION 2 / SPØRGSÆL 2
If 93 MWh of energy is used to heat the pools every year and another 10 MWh is used for LED lighting, how many efficient homes (6 MWh per year) can *The Cloud* power?

Hvis 93 MWh af energien anvendes til opvarmning af poolerne og yderligere 10 MWh anvendes til LED-belysning, hvor mange effektive hjem (6 MWh pr. år) kan *The Cloud* forsyne med elektricitet?
A “cloud” is a visible mass of condensed water vapor floating in the atmosphere, typically high above the ground. With regard to fractals in mathematics, a cloud can refer to a set of multidimensional points. The Cloud exists as a visual metaphor— the image of a fractal that is both illustrative and abstract. It can be described as being both solid and hollow. It is mathematically predictable, while also being ever-changing.

The Cloud is conceived as a social gathering point, where activities, such as swimming and enjoying the weather, can take place. It is an alternative, self-powered pool area, which is accessible both summer and winter.

The Cloud uses the geometry of the sphere in its facade. The circular wings of the turbines reflect natural and artificial light and, while moving, visually interact with the surroundings and the inside space. When each turbine reaches a certain speed, the edges of the blades become invisible to the eyes and transform into a three-dimensional shape with a diffused, misty, white surface. The Cloud measures 28 meters at its highest point. Though the cloud is a structure of symbolic status, the height is low and similar to the buildings found in the City of Copenhagen to better integrate it into the landscape.


The Cloud er tænkt som et socialt samlingspunkt, hvor aktiviteter, som svømning og nyden af vejret, kan finde sted. Det er et alternativt, selvforsynende poolområde, som kan anvendes både sommer og vinter.

QUESTION 1 / SPØRGSMÅL 1

Some of the energy that passes through the mouth of the collector is given over to sound energy. This key conceptual component of The Sound of Denmark reduces the capacity factor by 4.2% (they would otherwise operate at 40% of peak capacity). Assume that there are four of each size of turbine and that they all operate at 35.8% of full nameplate capacity. What is the total annual output of the entire installation?

Noget af den energi der passerer gennem hornets åbning anvendes til lydenergi. Denne vigtige konceptuelle komponent af The Sound of Denmark reducerer kapacitetsfaktoren med 4,2 % (hornene ville ellers fungere ved 40 % af peak-kapaciteten). Hvis vi formoder, at der er fire af hver størrelse vindmølle, og at de alle fungerer ved 35,8 % af fuld nominal kapacitet, hvad er så den samlede årlige effekt af hele installationen?

QUESTION 2 / SPØRGSMÅL 2

Why are The Sound of Denmark’s wind turbines facing open to the southwest?

Hvorfor vender vindmøllernes åbninger i The Sound of Denmark mod sydvest?

NAMEPLATE CAPACITY / SPIDSKAPACITET

<table>
<thead>
<tr>
<th>Diameter (m)</th>
<th>Capacity (kWp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>5.0</td>
</tr>
<tr>
<td>5</td>
<td>2.55</td>
</tr>
<tr>
<td>3.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Vindmølle med en diameter på 7 meter = 5.0 kWp
Vindmølle med en diameter på 5 meter = 2.55 kWp
Vindmølle med en diameter på 3,8 meter = 1.8 kWp

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER

ducted wind turbines
vindmøller i rør
The force of the wind has carried the development of Denmark since ancient times. Wind strength assisted the Vikings as they colonized new lands, and now wind power provides renewable energy to Denmark. Because this natural force has always been rooted in the development of the country, the wind is the sound of Denmark. The Sound of Denmark creates a space for reflection and to feel this natural force that drives Denmark. It is a space for remembering the past and envisioning the future. It is a sound-landscape.

The Sound of Denmark consists of four Viking horn trios, each trio consisting of a large, medium, and small horn. The largest horn is carved with the letter of the alphabet that refers to the natural force “sun.” The next in size is carved with the letter that refers to the natural force “water.” And the smallest horn is carved with the letter that refers to the natural force “ice.”

The technology—compact wind acceleration turbine—concentrates the wind and increases its velocity as it passes through the horns. Each Viking horn is comprised of four wind turbines, and the tubular shape makes the lower part of the horn function as a sounding board. Each horn is composed of materials, such as wood and metal, obtained from the hulls of decommissioned ships. In this way, all principal materials used in the project are obtained from waste so that the environmental impact is minimal. In turn, the material has a direct relationship with the industrial and maritime history of its surroundings.


The Sound of Denmark består af fire vikingehorntrioer, hvoraf hver trio består af et stort, et mellemstort og et lille horn. Det største horn er udskåret med det bogstav i alfabetet, der refererer til den naturlige kraftkilde “sol.” Den næste størrelse er udskåret med det bogstav, der refererer til den naturlige kraftkilde “vand.” Og det mindste horn er udskåret med det bogstav, der refererer til den naturlige kraftkilde “is.”

QUESTION 1 / SPØRGSMÅL 1
There are 46,400 meters of 1.5 meter wide OPV ribbon. Assume a capacity factor of 8% for the OPV, and that the piezoelectric poles contribute 230 MWh of electricity each year. What is the total annual output of Beyond the Wave?

Der er 46.400 meter med OFV-bånd, der er 1,5 meter bredt. Lad os formode en kapacitetsfaktor på 8 % for OFV, og at de piezoelektriske pæle bidrager med 230 MWh elektricitet hvert år. Hvad er den samlede effekt af Beyond the Wave?

QUESTION 2 / SPØRGSMÅL 2
Electrodynamics soil remediation technology at the bottom of each pole will serve the purpose of purifying contaminated soils. OLED lights on the bottom of the ribbon will illuminate the installation at night. Together these will consume 500 MWh of electricity each year. After this deduction, how many super-efficient apartments (3.2 MWh per year) will Beyond the Wave be capable of powering?

Elektrodynamisk jordrensningsteknologi i bunden af hver pæl har til formål at rense forurenet jord. OLED-lys i bunden af båndet vil belyse installationen om natten. Sammen vil disse forbruge 500 MWh elektricitet hvert år. Efter denne fratrækning hvor mange supereffektive lejligheder (3,2 MWh pr. år) kan Beyond the Wave så forsyne med elektricitet?

NAMEPLATE CAPACITY / SPIDSKAPACITET
organic photovoltaic panel: 82 watts per m² (Wp)
organisk fotovoltaisk panel: 82 watt pr. m² (Wp)

ENERGY TECHNOLOGIES / ENERGITEKNOLOGIER
organic photovoltaic panel (OPV)
piezoelectric poles
organisk fotovoltaisk panel (OFV)
piezoelektriske pæle
Inspired by the diverse and dynamic kinetic art of Len Lye, the undulating ribbons and flexible poles of *Beyond the Wave* creates movement through a contemplative environment. The location of the poles and ribbons are based on Copenhagen’s windrose (please see the glossary for more information about windrose diagrams) and soil survey map. Therefore, the frequency, density, and spacing between the poles are determined by the wind strength and intensity of the site.

The strength of the wind influences the varying movements of the flexible poles. The ribbon that connects the poles becomes the “wave,” reflecting the encounter between water and wind. The system takes advantage of solar power, and the pressure caused by the movements of the poles produce energy. The site is composed of an array of poles that are spaced for various human activities and movements.

The ribbons consist of transparent, organic, solar material that responds to the movement of the wind. The OPV Panel attached to the 1.5 meter-wide ribbon generates energy, which is partially used for OLED lighting. The display panel in the lower part of the pole indicates the amount of energy generated and the amount of CO₂ reduction, showcasing the energy saving effects in real time.

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**DESIGN TEAM**
Jaesik Lim, Ahyoung Lee, Sunpil Choi, Dohyoung Kim, Hoeyoung Jung, Jaeyeol Kim, Hansaem Kim

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**ANSWER 1 / SVAR 1**

- 1.5 m x 46,400 m (69,600 m²)
- × 82 Wp per m² nameplate capacity spidskapacitet
- × 0.08 capacity factor 0,08 kapacitetsfaktor
- × 365 days per year dage om året
- × 24 hours per day timer om dagen
- ∙ 1000000 (Wh -> MWh)

\[
\frac{4000 \text{ MWh per year pr. år}}{3,2 \text{ MWh per year per apartment pr. år lejlighed}} = 1093 \text{ apartments lejligheder}
\]
SKETCH ON THIS PHOTO

What does a sculpture that generates renewable energy look like for this site?

What aspects of the surrounding context inform the shape and the function of your artwork?

Who will interact with your design on a daily basis? Does your artwork reflect their cultural history and common interests?

What wildlife calls this site home? What types of plants are native to this area? How does your artwork cohabitate with these indigenous species?

Please either photocopy this flash card for creating multiple images to sketch on or use tracing paper on top of the flash card for your sketches.
SKETCH ON THIS PLAN PAGE

What technology or technologies are you using in your design? What devices are making energy?

In what way are you using the technology differently from how it is usually used?

Was your design inspired by something such as a natural object or another work of art?

How big is your artwork? Can people interact with it?

What do you want your artwork to communicate?

What else can you tell others about your piece?

Please either photocopy this flash card for creating multiple images to sketch on or use tracing paper on top of the flash card for your sketches.
TEGN PÅ DETTE FOTO

Hvordan ser en skulptur ud, der producerer vedvarende energi, på dette sted?

Hvilke aspekter i den omgivende helhed informerer dit kunstværks form og funktion?

Hvem vil interagere med dit design på daglig basis? Kan dit kunstværk afspejle beskueres kulturhistorie og fælles interesser?

Hvilke dyr har dette sted som habitat? Hvilke type planter hører til i dette område? Hvordan bor dit kunstværk side om side med disse arter, der hører til stedet?
GENERERING AF IDEER

TEGN PÅ DENNE SIDE

Hvilken teknologi eller teknologier anvender du i dit design? Hvilke enheder producerer energi?

På hvilken måde anvender du den, der er anderledes end den måde, teknologien normalt anvendes på?

Var dit design inspireret af noget, som et naturligt objekt eller et andet kunstværk?

Hvor stort er dit kunstværk? Kan mennesker interagere med det?

Hvad vil du gerne kommunikere med dit kunstværk?

Hvad kan du ellers fortælle os om dit værk?

Refshaleøen: København, Denmark

dimensioner er i meter
The Land Art Generator Initiative (LAGI) brings together artists, architects, scientists, landscape architects, engineers, and others in a first of its kind collaboration. The goal of the Land Art Generator Initiative is to see to the design and construction of public art installations that uniquely combine aesthetics with utility-scale clean energy generation. The works will serve to inspire and educate while they provide renewable power to thousands of homes around the world.

The images that you see on the Art+Energy Flash Cards are examples of submissions to the LAGI international design competitions held for sites in Abu Dhabi & Dubai, New York City, and Copenhagen. Through these competitions creative minds from around the world have come together to solve issues related to climate change, energy consumption, and the aesthetic needs of our communities.

More information about the Land Art Generator Initiative can be found at www.landartgenerator.org.

Cover image:
Heliofield
Michael Chaveriat, Yikyu Cho, Myung Kweon Park

Center image:
Beyond the Wave
Jaenil Lim, Kyungmun Lee, SungYi Cho, Dohyung Kim,
Hyejeong Jong, Jiyoung Kim, Hoojoon Kim